THE YEAR IN SCIENCE

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January/February 2015

100 TOP STORIES OF 2014

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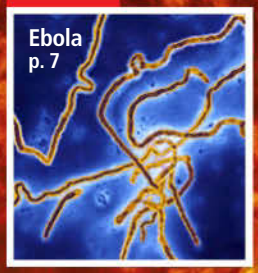
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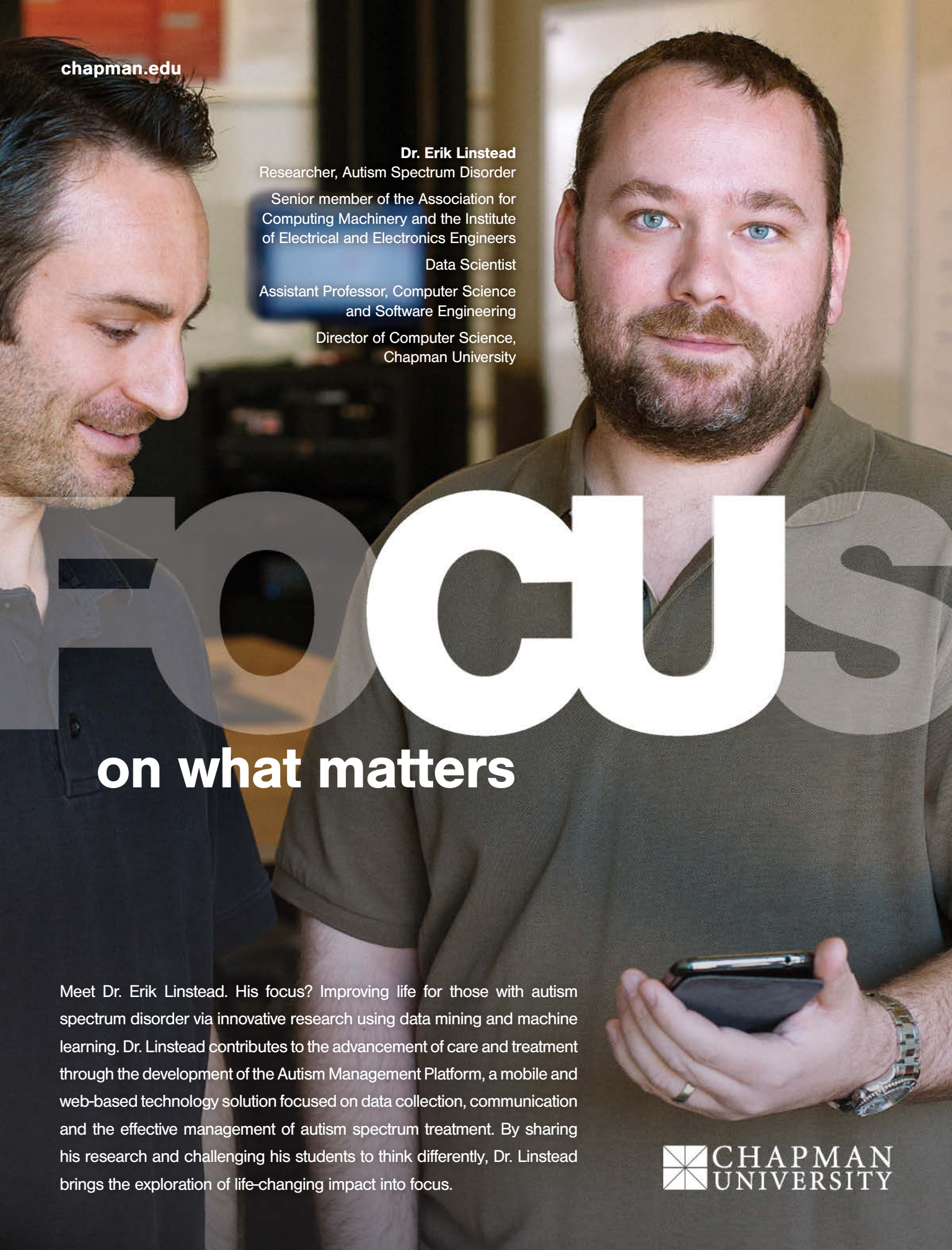




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chapman.edu



Dr. Erik Linstead
Researcher, Autism Spectrum Disorder

Senior member of the Association for Computing Machinery and the Institute of Electrical and Electronics Engineers

Data Scientist

Assistant Professor, Computer Science and Software Engineering

Director of Computer Science, Chapman University

FOCUS

on what matters

Meet Dr. Erik Linstead. His focus? Improving life for those with autism spectrum disorder via innovative research using data mining and machine learning. Dr. Linstead contributes to the advancement of care and treatment through the development of the Autism Management Platform, a mobile and web-based technology solution focused on data collection, communication and the effective management of autism spectrum treatment. By sharing his research and challenging his students to think differently, Dr. Linstead brings the exploration of life-changing impact into focus.

CHAPMAN UNIVERSITY

JANUARY/FEBRUARY 2015

100 TOP STORIES OF 2014



A microscopic view of the highly infectious Ebola virus.

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One of the deadliest viral outbreaks in recent history caught the world off guard, sending health experts and scientists scrambling to find a solution.

BY KARI LYDERSEN

Editor's Note

Welcome to our Year in Science edition, an issue so jam-packed with great stories that I have maybe 75 words to tell you about it. But I don't need more than that: These top 100 science stories from 2014 (plus bonus content, such as our New Species spotlights, peppered throughout the following pages) speak for themselves. Enjoy the issue, and don't forget to vote for your own top science stories at **DiscoverMagazine.com/YearInScience**.

Stephen C. George, EDITOR IN CHIEF

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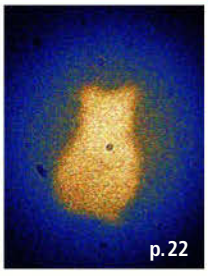
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Vote for your own top science stories at **DiscoverMagazine.com/YearInScience**

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FROM LEFT: PAUL NICKLIN/NATIONAL GEOGRAPHIC; REBECCA HALE/NATIONAL GEOGRAPHIC; GABRIELA BARRETO LEMOS

King Solomon's Secret Treasure: FOUND

Ancient beauty trapped in mines for centuries is finally released and available to the public!

King Solomon was one of the wealthiest rulers of the ancient world. His vast empire included hoards of gold, priceless gemstones and rare works of art. For centuries, fortune hunters and historians dedicated their lives to the search for his fabled mines and lost treasure. But as it turns out, those mines hid a prize more beautiful and exotic than any precious metal: chrysocolla.

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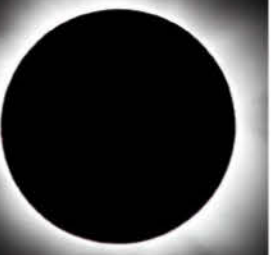
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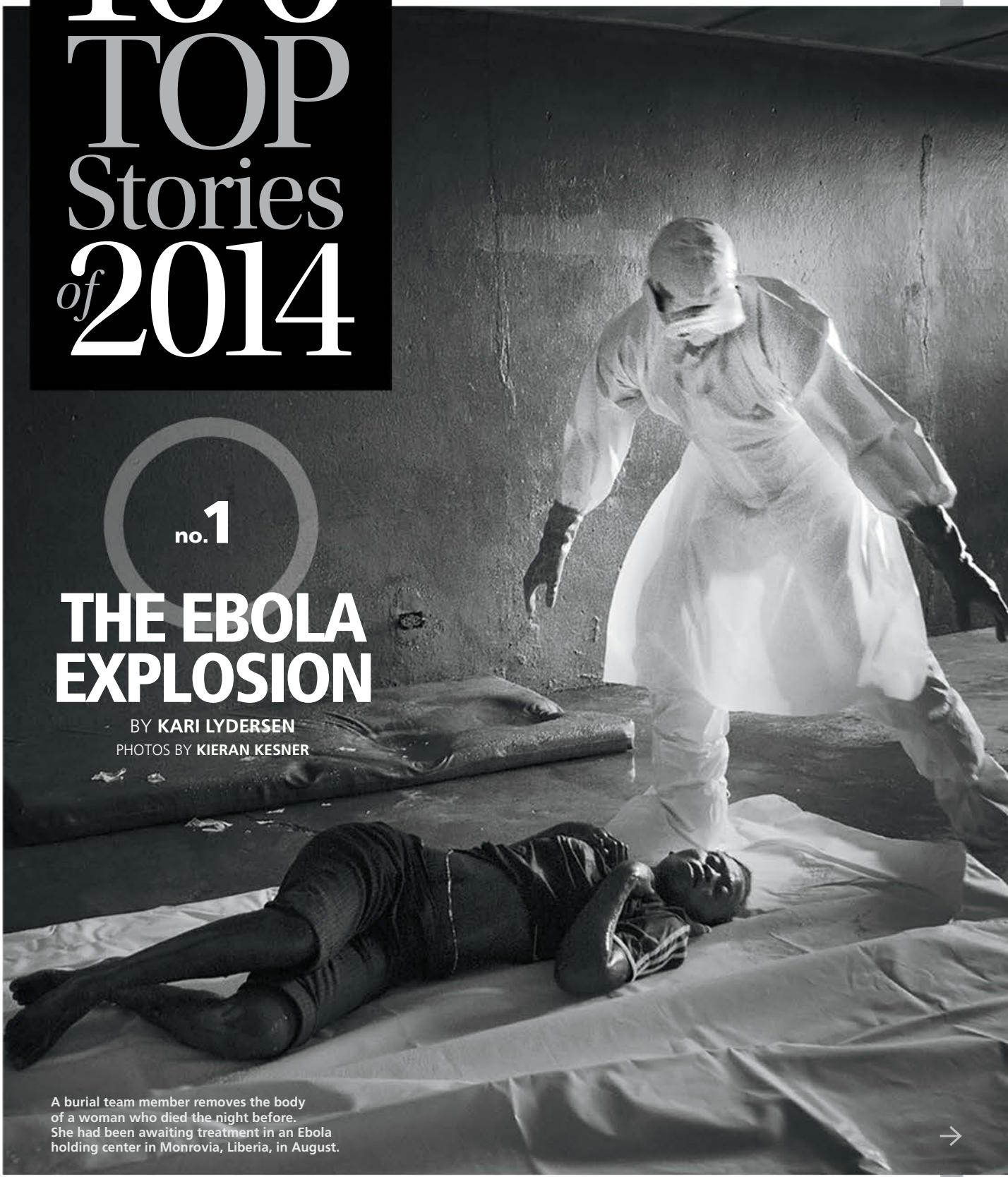
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100 TOP Stories of 2014



no. 1

THE EBOLA EXPLOSION

BY **KARI LYDERSEN**

PHOTOS BY **KIERAN KESNER**

A burial team member removes the body of a woman who died the night before. She had been awaiting treatment in an Ebola holding center in Monrovia, Liberia, in August.

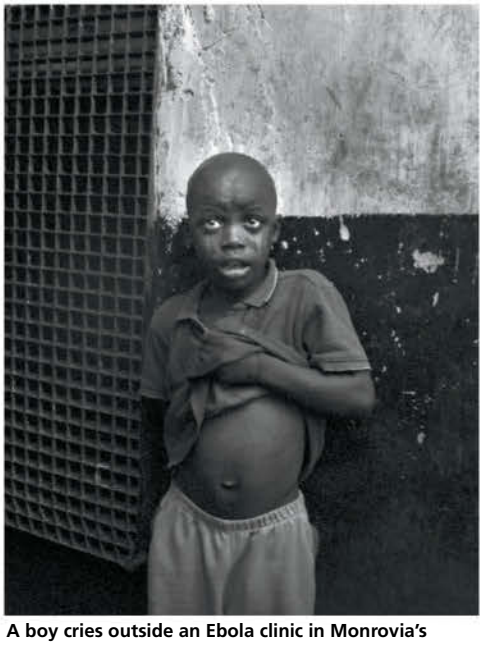
It started quietly, deep in the forest of southern Guinea.

In Meliandou, a village in the prefecture of Guéckédou, a 2-year-old boy contracted the virus, possibly from a fruit bat. The child's flu-like symptoms at first would have caused little alarm. But before long he began vomiting, and his stool was black with blood.

The young boy died on Dec. 6, 2013. By New Year's Day, his mother, sister and grandmother were dead. A month later, so were two mourners who had attended the grandmother's funeral, a local nurse and the village midwife. Before they died, the two mourners and the midwife carried the virus to nearby villages and to the region's hospital, infecting others.

Thus began the worst Ebola outbreak the world has ever seen.

By last summer, people across Guinea, Sierra Leone and Liberia had retreated to their homes, unwilling or unable to get to clinics where they'd seen their friends and relatives go, never to return. Health care workers labored in sweltering facilities. More than 200 succumbed to the virus, and frightened staff fled their positions, forcing clinics to turn patients away.



A boy cries outside an Ebola clinic in Monrovia's impoverished West Point district, where riots broke out and food ran short in August.

Since the Ebola virus first emerged in 1976 in the Democratic Republic of Congo (then Zaire), flare-ups had occurred mostly in isolated Central African forest villages. News of Ebola's lethality and its horrific symptoms — vomiting, diarrhea, and sometimes bleeding from the eyes, nose and other orifices — bred morbid curiosity and fear, and the gripping story of its emergence inspired the best-selling book *The Hot Zone*.

Despite Ebola's ferocity, previous outbreaks infected a few hundred people at most. Ebola is highly infectious — just a few particles of the virus in a drop of sweat or blood can cause disease — and health workers must don personal protective suits and quarantine patients in isolation units.

But the virus is not especially contagious. It's transmitted only via close contact with a patient's bodily fluids, excretions, soiled clothing or bedding. And patients are contagious only when they are palpably and visibly ill, making carriers easy to spot. All this helped health workers corral past outbreaks, and before long the virus would retreat into the forest.

Not this time. Why, in 2014, did Ebola spread sickness and death through West Africa and beyond — and how can science help stop it?

A PERFECT STORM

Robert Garry knew early on that trouble was brewing. He was working at Kenema Government Hospital in Sierra Leone last March when he heard reports of Ebola in neighboring Guinea. He was there studying Lassa fever, a cousin of Ebola. At the time, 112 people had been infected and 70 had died from Ebola, but the World Health Organization (WHO) said Guinea's outbreak was "relatively small still," and Guinean officials said it was under control.

Garry, a virologist from Tulane University in New Orleans, knew a thing or two about how outbreaks of Lassa, Ebola and related viruses play out. "Lassa simmers," he says. "Ebola explodes."

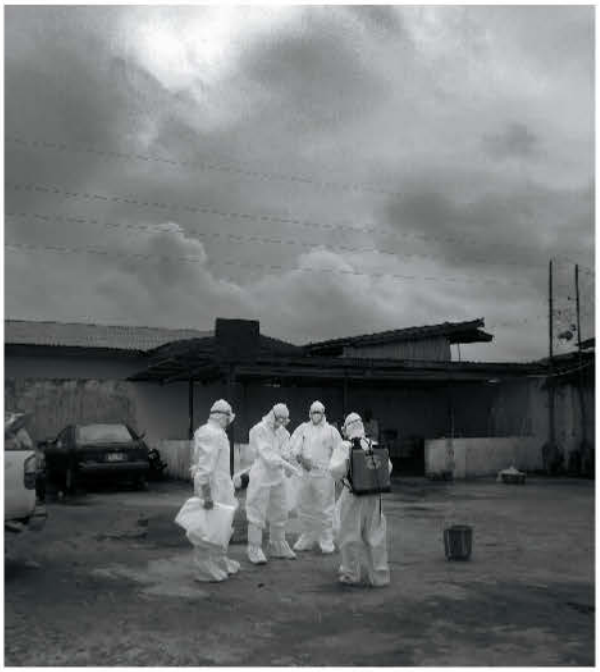
And as the international community dozed, an outbreak detonated. Through the spring and summer of 2014, Ebola swept through Guinea and into its neighbors, Sierra Leone and Liberia.

The 2014 Ebola epidemic, the first in West Africa, was driven by a confluence of factors: poverty and lack of health care infrastructure; traditional burial practices that helped spread the disease; deep-seated mistrust of Westerners, health care workers and authorities; and the region's growing mobility.

In May, women from Sierra Leone attended the funeral of a traditional healer who had treated Ebola patients across the border in Guinea. One of the mourners, a young pregnant woman, showed up at Kenema Government Hospital, where she miscarried and was diagnosed with Ebola. In all, 14 of the mourners were infected and spread the virus to their contacts in Sierra Leone, stoking that country's epidemic, according to a DNA-sequencing study that Garry, renowned Sierra Leonean virologist and doctor Sheik Humarr Khan, Harvard virologist Stephen Gire and 55 colleagues later published in *Science*.

Garry and some colleagues, including Khan, readied the Kenema Government Hospital for Ebola patients. Soon he returned to the U.S., where he contacted federal officials to express his fears about a brewing epidemic. He received only "polite responses," he says.

Meanwhile, in Monrovia, Liberia's capital, physician and Christian missionary Kent Brantly began setting up that country's first Ebola isolation ward. Before long



A team in the West Point district prepares to enter a holding center to retrieve the bodies of Ebola victims.

the disease took hold in Monrovia's dense slums, filling Brantly's ward to overflowing.

"The disease was spiraling out of control, and it was clear we were not equipped to fight it effectively on our own," Brantly testified later to the U.S. Senate. He said he and his colleagues "began to call for more international assistance, but our pleas seemed to fall on deaf ears."

On Aug. 8, WHO finally declared the epidemic a public health emergency of international concern. "No one was really imagining we would get to this situation," WHO spokesman Tarik Jasarevic says. Within weeks, Liberia had surpassed Sierra Leone as the outbreak's epicenter. By then, more than 2,400 had been infected and 1,346 had died.

SCIENTISTS SCRAMBLE

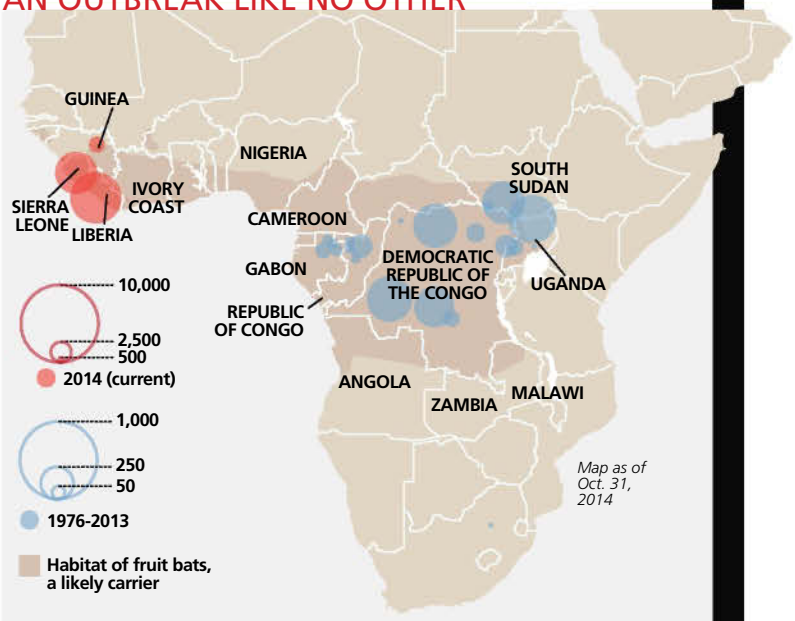
Ebola's spread caught many scientists off guard at first. They knew that shortly after infection, the Ebola virus commandeers or kills immune cells, weakening the body's defenses and letting the virus run wild. They also knew that the virus interferes with blood clotting, which leads to bleeding and, in many cases, multiple organ failure.

But no proven therapy or vaccine existed at first, in part because of long-standing funding shortfalls for diseases that mostly affect the developing world. By summer, however, researchers worldwide were racing to the lab to combat the epidemic.

At least four experimental Ebola drugs were in early stages of development. The first human

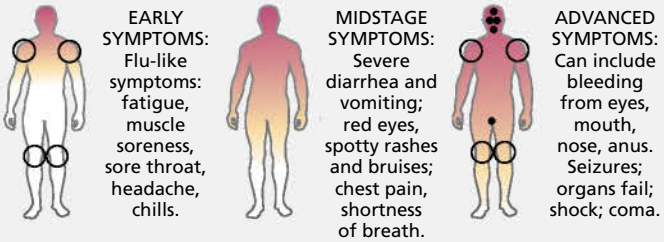
ILLUSTRATION: JAY SMITH

AN OUTBREAK LIKE NO OTHER



WORSENING SYMPTOMS

INFECTION: Ebola virus enters through eyes, mucus membranes or tiny cuts or scrapes. Symptoms typically appear four to 10 days later.



EARLY SYMPTOMS: Flu-like symptoms: fatigue, muscle soreness, sore throat, headache, chills.

MIDSTAGE SYMPTOMS: Severe diarrhea and vomiting; red eyes, spotty rashes and bruises; chest pain, shortness of breath.

ADVANCED SYMPTOMS: Can include bleeding from eyes, mouth, nose, anus. Seizures; organs fail; shock; coma.

EBOLA INVADES

Like many other filoviruses, Ebola has an RNA genome and causes severe hemorrhagic fever. It hijacks the cell, making proteins that help it multiply and disable immune defenses.

Viral proteins coat the RNA genome. The virus then assembles and buds from the cell.

To enter a cell, Ebola binds to a protein on the surface. The cell engulfs the virus, which disassembles inside the cell.

Ebola makes viral messenger RNA (blue) and uses the cell's ribosome (green) to make its proteins (red lollipops).

Ebola copies its RNA genome (red).

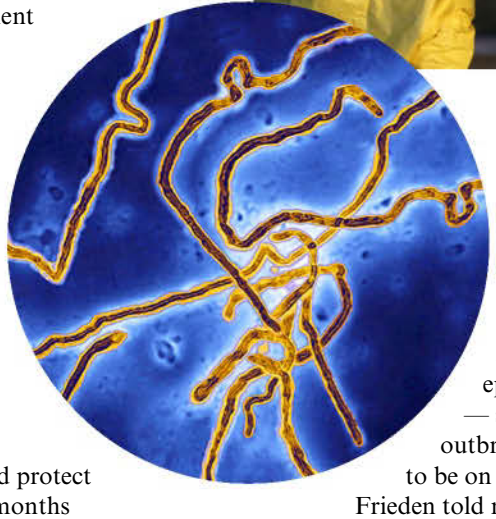
safety trial on an Ebola drug began in January 2014 for TKM-Ebola, which contains snippets of RNA produced by Tekmira Pharmaceuticals that target three genes essential to viral replication. But it was ZMapp that grabbed the headlines. This cocktail of three antibodies, from San Diego-based Mapp Biopharmaceutical, binds to Ebola, neutralizes it and alerts the immune system to the infection. As of last summer, it had not been tested in people.

In July, Khan contracted Ebola. Physicians with the nonprofit group Doctors Without Borders, which led early efforts to combat the epidemic, agonized about whether to treat him with ZMapp. They feared that he might die, spurring even more mistrust of health care workers, and they decided not to. In late July, Khan died in a Doctors Without Borders clinic in Kailahun, Sierra Leone. He was 39.

Just days earlier in Monrovia, Brantly and a fellow American missionary, aid worker Nancy Writebol, were also diagnosed. They received a few of the ZMapp doses available and were then flown to Emory University Hospital in Atlanta. After several harrowing weeks in intensive care, they recovered.

By September, the first reports had appeared showing that ZMapp effectively fights Ebola in monkeys, and the U.S. government pledged $25 million to help Mapp Biopharmaceutical manufacture more of the drug, test it in clinical trials and get it approved for human use.

To protect people from infection, researchers also developed two different vaccines, each with a key Ebola protein sewn into a harmless virus. One of the vaccines, developed by scientists at the pharmaceutical giant GlaxoSmithKline and the National Institute of Allergy and Infectious Disease (NIAID), helped protect monkeys from Ebola infection 10 months after vaccination. NIAID then launched a clinical trial to test the vaccine's safety, and GlaxoSmithKline committed to making 10,000 doses for health care workers by the end of 2014.



TOO LITTLE, TOO LATE

In September, the international community finally woke up to Ebola's threat. President Barack Obama promised to send 3,000 troops to Liberia and build 17 treatment centers with 100 beds each. But by then, about 7,200 people had been infected, more than 3,300 had died, and the casualties were skyrocketing. Researchers at the Centers for Disease Control and Prevention built computer models, which predicted that, if a massive intervention failed to materialize, by January 2015 up to 1.4 million people could be infected.

The epidemic finally hit home for many Americans on Sept. 30, when Thomas Eric Duncan, a Liberian visiting Dallas, became the first person diagnosed on U.S. soil. He was isolated and treated intensively, but he succumbed just eight days later. Then two nurses who



It takes very little Ebola virus (left), to cause disease, so this Texas worker wore full protective gear while cleaning up outside the home of an infected health care worker.

treated Duncan at a Dallas hospital were diagnosed, becoming the first-ever cases of Ebola transmission on American soil, and a different epidemic — this one of anxiety — swept the nation. "As long as the outbreak continues in Africa, we need to be on our guard," CDC director Tom Frieden told reporters.

It will be difficult to eliminate the virus entirely, since Ebola lurks in animals and periodically jumps to humans, Harvard's Gire says. But we can corral it by better diagnosing and treating infections, and by setting up labs on the ground to track emerging Ebola strains by sequencing their genomes. "Constant surveillance is the only way to be sure we know where the virus is going," he says. "It's imperative."

Read the latest updates on the Ebola outbreak at **DiscoverMagazine.com/Ebola**

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Climate in Crisis

2

West Antarctic Ice Sheet Collapses

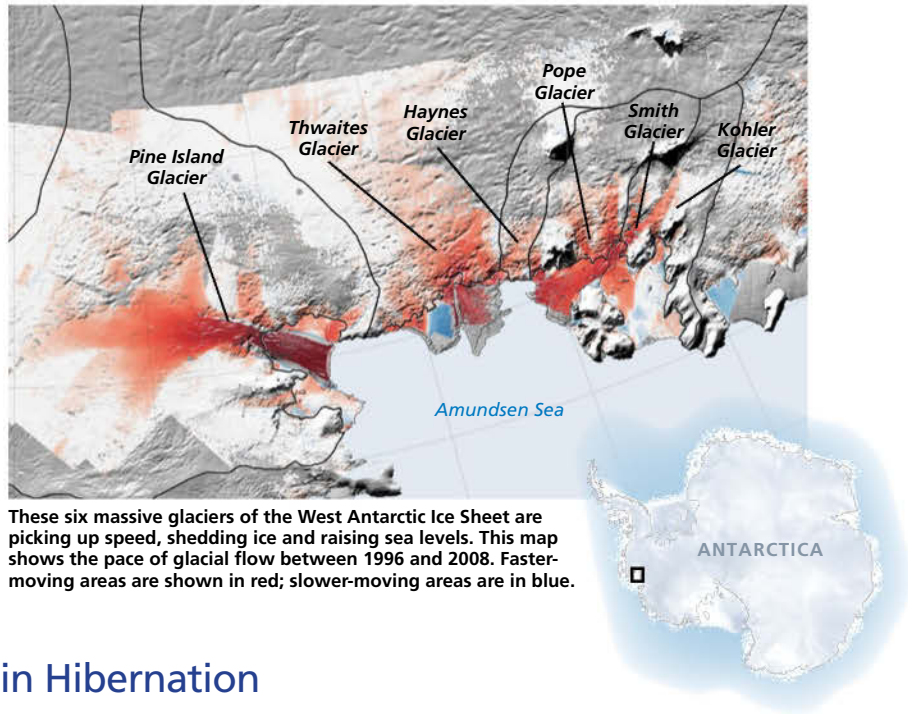
Imagine you're canoeing the Niagara River when you notice mist ahead. You're still quite a distance from Niagara Falls, but the river's swift: There's no turning back.

Two separate studies published last spring suggest that climate change has carried the West Antarctic Ice Sheet, or WAIS, across a similar threshold. The glaciers that flow off WAIS and dump ice into the sea already have contributed nearly 10 percent to the recent increase in global sea levels. Now, warming seawater intruding underneath has loosened the glaciers' grip on bedrock, speeding their flow toward the sea and causing increasing amounts of ice to break off into the ocean.

The research suggests that for a large portion of WAIS, this process "has passed the point of no return," says Eric Rignot of the University of California, Irvine, the lead author of one of the studies. That means the ice sheet is now in irreversible retreat, and steps to slow global warming won't stop the ice sheet from raising the sea level 10 feet, swamping cities.

But there is a silver lining: Full collapse may take centuries, perhaps providing time to move populations at risk out of the way.

—TOM YULSMAN



These six massive glaciers of the West Antarctic Ice Sheet are picking up speed, shedding ice and raising sea levels. This map shows the pace of glacial flow between 1996 and 2008. Faster-moving areas are shown in red; slower-moving areas are in blue.

Climate Change Is Not in Hibernation

As brutal Arctic conditions gripped large parts of North America in the winter of 2014, it was tempting to think that global warming had vanished.

But along with the notorious polar vortex, the year also brought new evidence that human activities are altering the climate in ever more obvious ways — and that the risks of severe impacts rise with every ton of greenhouse gases emitted into the atmosphere.

"Climate change is real," says Gerald Meehl, a scientist with the National Center for Atmospheric Research (NCAR) in Boulder, Colo. "Humans are causing most of it, we can measure it better than before, we have good tools to measure it in the future, and it's going to be ongoing."

There's no denying 2014 got off to a weird start. The strong winds that normally corral a pocket of frigid air over the North Pole took a detour, allowing a giant blob of Arctic iciness to drop as far south as the Gulf Coast.

Some declared global warming dead. Others argued it was cold *because* of global warming, pointing to inconclusive evidence that it had weakened polar vortex winds that normally keep Arctic air in the Arctic.

But while the "Arctic blanket" got all the attention, it didn't tell the whole story. Just ask a Californian, Alaskan or Finn. The same contortions of the polar vortex that blasted more than half of the U.S. allowed unusual warmth to spread north to Alaska, which was 14 degrees Fahrenheit warmer in January than the long-term average. In California, above-normal temperatures exacerbated a drought that reached historic proportions by summer. And in Finland, warm and wet conditions forced bears out of winter hibernation.

However unusual they may have been, the hot spells here and cold snaps there were examples of weather — the day-to-day variations in the state of the atmosphere. It's how those variations add up over several decades that gives you climate. And when you look at global averages over decades, it's clear that climate change has *not* gone

MOUGINOT, RIGNOT, SCHEUCHL/UNIVERSITY OF CALIFORNIA IRVINE/JPL

into hibernation. "Each one of the last three decades has been successively warmer at Earth's surface than any preceding decade since 1860," Meehl says.

GLOBAL 'SLOWDOWN' EXPLAINED

Although decade by decade, Earth's average surface temperature has risen, that trend has flattened over the past 10 years. In 2014, scientists started to figure out why. At least part of the answer may be that climate measurements are underestimating the amount of surface warming actually taking place.

It's tricky to take Earth's temperature because the poles have few weather stations, creating gaps in thermometer data. In a study published in February, scientists found that when satellite and other data are used to fill in the blanks for the Arctic — where glaciers and sea ice have been shrinking rapidly — a stronger global warming trend emerges.

"If you put the Arctic back in the picture, there's much less of a slowdown in global average temperature, and nothing that looks like a plateau," says Richard Alley, a climate scientist at Pennsylvania State University.



This satellite image from late January 2014 shows the extent of the polar vortex's reach across the United States.

NOAA/NASA GOES PROJECT

It also looks like nature is tucking a lot of heat away in the deep oceans. Research published in 2014 by Chinese and American scientists pointed to heat plunging into the Atlantic Ocean as a major factor in the leveling off of global surface temperatures.

Meanwhile, a study by NCAR senior scientist Kevin Trenberth and colleagues suggested that the Pacific Ocean is playing the most significant role, thanks to a phenomenon called the Pacific Decadal Oscillation. The oscillation is a pattern of climate variability akin to El Niño and La Niña — weather patterns caused by periodic warming and cooling of ocean temperatures in the Pacific — except it is longer-lived. It has been in a cool, La Niña-like phase for 10 years, causing heat to sink deep into the Pacific. The oscillation also has triggered a chain of atmospheric waves — rippling out like a boat's wake — ultimately making Eurasia in particular cooler than it otherwise would have been, Trenberth says.

Couldn't this cool, La Niña-like state go on for a while? As 2014 progressed, there were hints that it might not. First, the opposite of La Niña — a warmer, El Niño condition — began to emerge in the Pacific early in the year. And that summer turned out to be the warmest on record, putting 2014 on track toward record global warmth.

WIDESPREAD IMPACTS

Whether or not Earth's average temperature continues to rise in the coming year, this one factor won't reveal the full picture of climate change, just as taking a person's temperature doesn't reveal the full picture of an illness. Fevers can fluctuate even as other symptoms intensify.

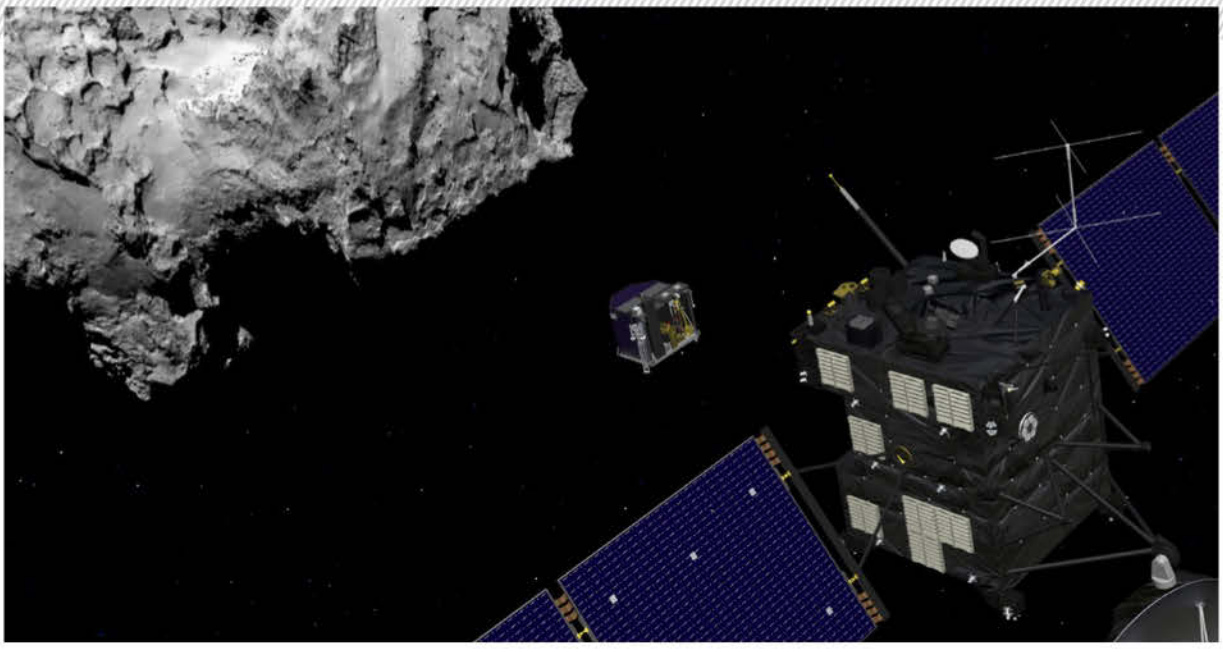
And symptoms of global climate change are already widespread — and growing. A report in 2014 from the National Oceanic and Atmospheric Administration pointed to human-caused climate change as a significant influence on some extreme weather events in 2013 — notably heat waves in Europe, Asia and Australia. And overall, climate change now affects agriculture, human health, ecosystems, water supplies and the livelihoods of people, according to a major 2014 report from the Intergovernmental Panel on Climate Change. "In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans," the report notes.

Agricultural impacts are of particular concern, since the global population is expected to increase from more than 7.1 billion people to about 9.5 billion by 2050. To feed all those people, agricultural productivity will have to keep pace. But according to the IPCC, climate change already has slowed productivity for some crops. For example, global wheat production has dropped 2 percent per decade in the past 30 years.

Looking forward, research published in late July showed that expected climate change over the next 20 years substantially raises the risk that rising food production will fail to keep up with increasing demand.

"These kinds of studies should be a reminder that we are changing the climate enough to create consequences on things like our livelihoods and what we expect of food availability," says Claudia Tebaldi of NCAR, a co-author of the study. "We are playing around with things that are important, and we should do something about slowing the pace of change, if not reversing it." —TOM YULSMAN

Read the latest updates on climate science at the author's blog: **DiscoverMagazine.com/Imageo**



Rosetta's Comet Rendezvous Makes Space History

On Aug. 6, the European Space Agency's Rosetta spacecraft went where no man, or probe, had gone before: into orbit around a comet. The rendezvous marked the end of a 4 billion-mile journey and the start of a 17-month orbital mission designed to understand the changes comets undergo as they approach the sun.

Because comets contain material from when the sun and planets formed, Rosetta can answer questions about the evolution of the solar system and the origin of water (and possibly life) on Earth.

Just weeks after arriving near Comet 67P/Churyumov-Gerasimenko, Rosetta delivered the sharpest-ever views of a nucleus — the frozen mass of rock and ice at a comet's heart. The spacecraft's camera revealed it as a double-lobed object that some mission scientists referred to as a "rubber ducky," complete with a head, neck and body. Pocked with craters and littered with boulders, the nucleus measures about 2.5 miles across at its widest.

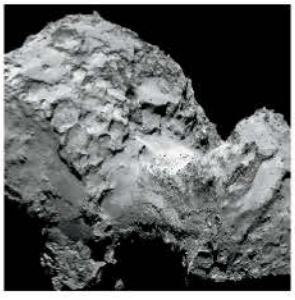
As of press time, Rosetta is scheduled to drop a lander, named Philae, in mid-November onto a site on the comet's surface named Agilkia — another space exploration first. Together, the two spacecraft will map the comet's surface, analyze its chemical composition and study the gases and dust particles ejected as the sun's heat warms the ice in the nucleus. Philae should survive for a few months, and Rosetta will last until the end of 2015 or beyond, so the probes will be able to examine changes in 67P as it heads toward its closest approach to the sun in August. —RICHARD TALCOTT

Read the latest news on Rosetta at **DiscoverMagazine.com/Rosetta**



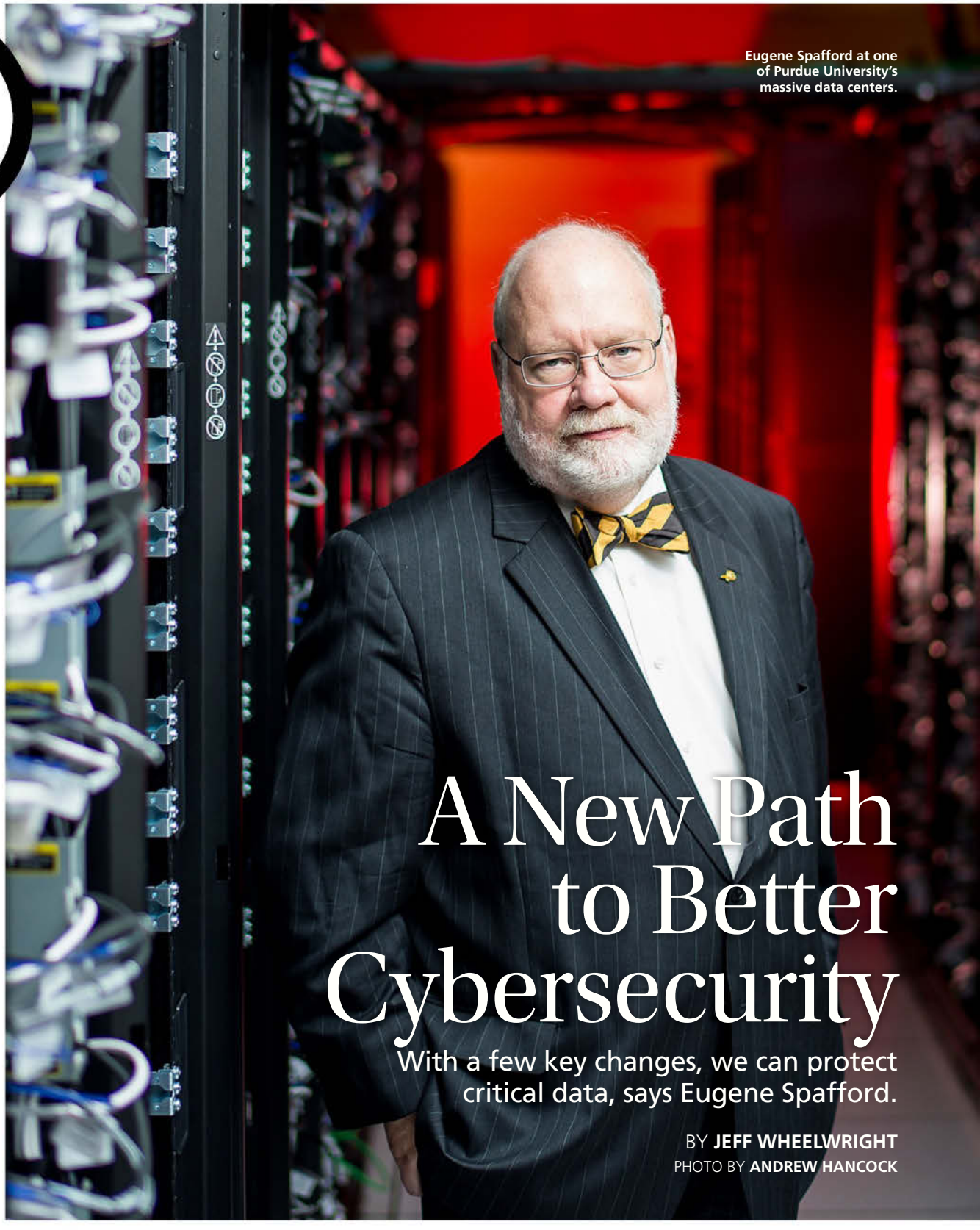






TOP: ESA/ROSETTA/MPS FOR OSIRIS TEAM MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA. BOTTOM: ESA/ROSETTA/MPS FOR OSIRIS TEAM MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA (3); SECOND IMAGE FROM LEFT, ESA/ROSETTA/NAVCAM/DAMIA BOUIC

4



Eugene Spafford at one of Purdue University's massive data centers.

A New Path to Better Cybersecurity

With a few key changes, we can protect critical data, says Eugene Spafford.

BY **JEFF WHEELWRIGHT**
PHOTO BY **ANDREW HANCOCK**



It was a terrible year for the health of computer systems. Cyberthieves stole credit- and debit-card numbers from up to 56 million customers of the retail giant Home Depot, even more than the 40 million they stole in 2013 from Target. At JPMorgan Chase, 76 million bank accounts were compromised. The Heartbleed bug poked a big hole in widely used encryption software, and the Bash bug exposed millions of computers to malware. A Russian gang made off with more than a billion email addresses and passwords and compromised a half-million websites.

What's going on, and what can we do about it? *Discover* spoke with Eugene Spafford, a longtime computer security expert and director of Purdue University's Center for Education and Research in Information Assurance and Security (CERIAS).

As you look over the recent incidents, what do they tell you about the state of our cybersecurity?

The Home Depot and Target breaches were examples of how our commercial infrastructure is very vulnerable to those who want to exploit it. As criminals increase their sophistication, they will pick bigger and more complex targets. That targeting won't be for the intellectual challenge — it will be because bigger targets have more to offer. Theft of millions of credit card transactions provides a huge body of information to break up and resell to other criminals. Theft of medical data, design and marketing plans, and financial information is a growing business with little in the way to discourage it.

It took months before the Home Depot and Target breaches were detected. It took more time before the companies patched their software, then assured customers that the patched systems were safe. Can we really trust that such ad hoc fixes to existing programs will protect us from credit card fraud?

The software industry has built a response mechanism around the idea that flaws in products can be patched and that somehow the "patchability" is a substitute for sound design. Unfortunately, as we have seen with a great many incidents, it takes time to discover and analyze each flaw, and the patches take time to apply. The Heartbleed and Shellshock (Bash) flaws took years to discover, for instance — with the Shellshock flaw reported as being present for nearly 25 years! Then, too, some flaws may never get fixed everywhere. This combination of factors means sloppy design is ensuring that our overall infrastructure will be riddled with vulnerabilities for the foreseeable future.

What about the theft of passwords by Russian gangsters?

It's unlikely we'll be able to identify and apprehend the people who've stolen all those passwords because of the difficulty of investigating and prosecuting computer crime. But for them to get the passwords means that they somehow found weaknesses in lots of vendors that they were able to exploit. The Target breach, the collection of passwords and a number of other incidents this year all point to a significant, well-funded, technically talented criminal element that is actively attacking and exploiting systems, from home users up to major corporations.

If you were the cybersecurity czar, what steps would you recommend?

This is an area that needs more fundamental research on how to change the way we build and deploy things, not simply on how to patch what's there. An awful lot of the federal research funding is, how do we fix Windows, how do we fix Linux, how do we make a stronger PC. That's not going back and questioning fundamental assumptions.

We are currently using general-purpose, mass-market computing platforms to do things that don't really require that level of generality. It makes them vulnerable to a wider variety of attack than they would be if they were custom-built.

If we build systems that do only one or two things, they're less likely to be attacked. Your microwave oven has software inside that's used to make it run. If that's not connected anywhere and it doesn't do anything else, like calculate your taxes and store your recipe files and send email, it can't be attacked by outside mechanisms. Yes, it might be more expensive to build a new system or to remove components from an existing system. But being in business means you also have a duty to your customers and society not to endanger them unnecessarily with what your product does.

We've also got to move the job of combating malicious cyberactivity away from the military and more into law enforcement. A lot of what the federal government does is that it tries to mandate from a centralized, top-down approach. By default, most information flows to a small number of federal agencies. That's not the right approach. What we really need is a local view.

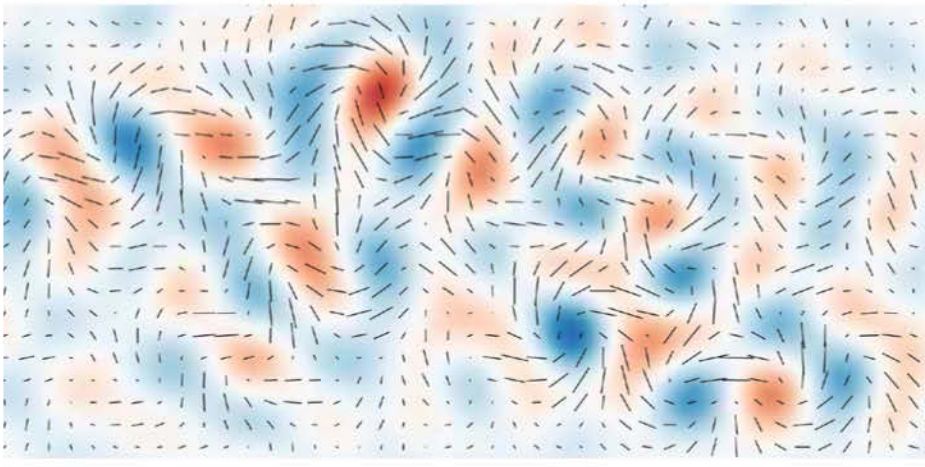
You've proposed a local extension service for small, local businesses, something akin to the agricultural extension service.

If you found an unusual proliferation of caterpillars eating everything in your garden, you wouldn't contact somebody in Washington to come look at them. You would find your local extension service, and you would take a sample in, and they would give you advice as to what it was and how to respond. I think we need to adopt that kind of model for cyber — have an extension service, at a local level, that people can go to for classes, advice as to what software to get and help to identify a problem.

5

What Made the Bang so Big?

Earlier in 2014, cosmologists thought they were finally closing in on an answer to that age-old question, "How did it all begin?" In March, Harvard astrophysicist John Kovac announced that a small telescope at the South Pole called BICEP2 (short for Background Imaging of Cosmic Extragalactic Polarization) had captured signals that apparently come from "the first trillionth of a trillionth of a trillionth of a second in the history of the universe."



This telltale swirling pattern of light may be evidence of cosmic inflation.

Independent confirmation was still needed, said Kovac, who heads the BICEP2 team, but if the result held up, it would mean scientists were on the verge of witnessing and understanding the moment of creation for our cosmos. Then data from the European Space Agency's Planck space telescope rolled in six months later, casting doubt over the earlier result. (See "Clouded by a Veil of Dust," opposite page.) The world won't know the final verdict until the BICEP2 and Planck scientists release their joint report.

Assuming its findings are validated, BICEP2 will have amassed the strongest support yet for cosmic inflation, a theory that attempts to explain exactly what happened during the Big Bang, the universe's explosive birth event. Inflationary theory holds that our newborn universe started as a tiny fleck of matter, less than one-billionth the size of a proton, and grew exponentially fast — expanding faster than the speed of light, in fact, while doubling in size at least 100 times.



The BICEP2 telescope in Antarctica looked for the cosmic pattern.

Inflation is the brainchild of MIT physicist Alan Guth, who came up with the idea in 1979. "I didn't think it would be tested in my lifetime," says Guth, because when he dreamed up the theory, no one could conceive of a practical way to verify it.

The runaway expansion lasted from about 10^{-36} of a second to 10^{-32} of a second after the Big Bang, but it would have deformed space violently enough to produce gravitational waves, just as a vibrating drumhead emits sound waves. These gravitational waves generated during inflation would be so weak by now, 13.8 billion years after the Big Bang, that they'd be undetectable. But in 1997, five physicists hit upon a possible strategy: Inflationary gravity waves could distort the light left over from the Big Bang in a discernible way.

Eons after the primordial blast, this remnant light fills all space, constituting a faint glow everywhere in the sky known as the cosmic microwave background, or CMB. The key lies in determining how that vestigial light is polarized — basically, how the light waves are oriented. Inflation-era gravity waves, which alternately stretch and compress space as they pass through, would leave a permanent mark in the cosmic radiation background, adding a twist to the CMB polarization. This distinctive, swirling pattern is called a B-mode. If astronomers could detect that, they would, in effect, see the fingerprint of inflation.

BICEP2 was specifically designed to look for this pattern. From 2010 to 2012, the telescope observed a small patch of sky visible from Antarctica. Kovac and his co-investigators — Jamie Bock of Caltech, Chao-Lin Kuo of Stanford and Clem Pryke of the University of Minnesota — then spent over a year scrutinizing the data. "We checked it 14 different ways to make sure it was consistent," Kovac says, before announcing they had identified the telltale vortex-like pattern expected from

TOP: BICEP COLLABORATION. BOTTOM: STEFFEN RICHTER, HARVARD UNIVERSITY

gravitational waves generated during inflation.

The researchers believe the signal they detected was cosmic in origin and did not come from our own galaxy, although that point has come under question. The big issue is whether the BICEP2 investigators properly accounted for the effects of dust within our own galaxy, as it could also have given rise to the swirling B-mode pattern.

While that's being straightened out, the BICEP2 team is moving ahead, poring over new data from the South Pole's Keck Array, which is part of the series of experiments co-led by Kovac and his colleagues. BICEP3, BICEP2's more sensitive successor, is set to begin a three-year observational run in early 2015. And several competing groups are going after the B-mode signal as well.

If the original claims are substantiated and the emerging picture of the universe's beginning is upheld, what would that mean? First, it would tell us that gravitational waves, predicted by Einstein's century-old theory of general relativity, really do exist. Second, it would greatly clarify our understanding of the Big Bang, telling us, as Guth puts it, "what banged and why it banged." Third, it would build an almost ironclad case for inflation.

Some uncertainty would still persist because cosmologists don't fully grasp the underlying physics behind inflation. But the story of our universe's first moments would, nevertheless, come into sharper focus than ever before — far beyond what many observers had deemed possible. — STEVE NADIS

CLOUDED BY A VEIL OF DUST

Euphoria overtook the science world on March 17, when members of the BICEP2 team announced the discovery of gravitational waves that represented the "first tremors of the Big Bang." A couple of months later, two independent analyses claimed the BICEP2 researchers had underestimated the effects of dust in our galaxy, as it could produce the pattern they had attributed to gravitational waves.

On Sept. 22, data from the Planck space telescope showed that the portion of the sky BICEP2 studied contained more galactic dust than previously assumed. The two teams have joined forces to determine whether the signal BICEP2 detected originated, at least in part, from gravitational waves, or if it's entirely explained by dust.

The results should appear in late 2014. Meanwhile, astronomers are continuing the kinds of observations undertaken by BICEP2, which are still regarded as the most promising means of witnessing the birth throes of our universe. — S.N.



COURTESY OF KINDMAN

Thousands of plants crowd a grow room owned by Kindman, a Denver cannabis dispensary. In 2014, Colorado became one of the first states to legalize the drug.

6

Marijuana Goes Legit, but the Future of Research Is Hazy

In 1969, Carl Sagan wrote anonymously that marijuana helped him reach "devastating insights." If he were writing today, he might use his real name. The stigma of dope is seemingly going up in smoke — but there are still surprisingly few studies on the drug.

In 2014, Alaska, Oregon and the District of Columbia legalized recreational marijuana, and sales began in Colorado and Washington, which adopted similar measures in 2012. Twenty-three states now allow the use of medical marijuana. In a February poll by the Pew Research Center, a majority of Americans — 54 percent — said pot should be legal. Just four years ago, 41 percent supported legalization.

But the growing acceptance of marijuana has done little to ease research restrictions. The federal government still classifies pot as a highly restricted drug, and it can take years to secure approval for studies. Even in states where researchers can legally buy top strains like Ghost Train Haze at the corner pot store for their personal use, they must use a single federally approved strain for their studies. Yet that strain is low on a chemical credited with many of the plant's touted medical benefits.

Philippe Lucas, vice president for research at Tilray, a medical marijuana producer in British Columbia, says America's loss is Canada's gain. There, a research project can use pot from a licensed producer.

So, is the ever-more-accessible drug safe to use? The few studies on marijuana yield no clear answer. Scientists have demonstrated that pot impairs driving, though other researchers say high drivers often compensate with added caution. Other studies suggest pot hammers short-term memory, and one found that frequent use can lower IQ, though it has received criticism for overstating the link. Research published in October suggests that regular pot smoking increases the risk of developing chronic bronchitis. As for marijuana's widely touted medicinal benefits, the scant research in that area suggests that chemicals in pot called cannabinoids may reduce pain and inflammation.

The FDA is considering reclassifying weed into a less restrictive category. If it does, much of the red tape would vanish, and researchers could be able to use retail strains in their studies — and not just as a Saganesque aid to creative scientific thinking. — EMMA MARRIS

7

Ancient Genome Sequences Settle First Americans Debate

A toddler boy and a teenage girl have settled a contentious debate in archaeology more than 12,000 years after their deaths.

In February, researchers published the first ancient American human genome, sequencing DNA from the remains of a boy known as Anzick-1, who was buried about 12,600 years ago in what is now western Montana. The child's genes proved conclusively for the first time that Native Americans are descended from an Asian population that migrated across Beringia — a land bridge now submerged between Siberia and Alaska — at least 15,000 years ago.

"The archaeological and genetic stories are beginning to mesh," says Mike Waters, an archaeologist at Texas A&M University and a member of the Anzick-1 team. "It's been a long-held belief that the First Americans gave rise to Native Americans, but having the genetics verified that there were direct or close ties."

Particularly satisfying to Waters, the findings refute a competing theory about First Americans. Based on similarities in tool design between the American Clovis culture, to which Anzick-1 likely belonged, and that of a southwestern European Ice Age culture, some researchers had been promoting the Solutrean hypothesis: that the Americas were first settled by Europeans who crossed the Atlantic, possibly in skin kayaks.



Arrows show the flow of human migration across the Bering land bridge from Asia.





A child's remains were found at the base of this cliff in Montana, along with Clovis tools (left).

"Anzick clearly shows direct descendency — and continuity — of Native Americans all the way back to Central Asia," Waters says. "The Solutrean ship has sunk."

Anzick-1's resting place is the oldest credible burial site found in the Americas — and the only one associated with the Clovis culture, known in particular for its fluted spear points. The child's remains were found in 1968 during construction on land belonging to the Anzick family.

Recognizing the find's scientific significance but aware of Native American cultural sensitivities, the family kept the remains secure for more than 40 years. They turned down several requests to study Anzick-1's remains until they were approached by Waters and University of Copenhagen paleobiologist Eske Willerslev.

Sequencing Anzick-1's genome was no easy task, according to Willerslev. "Without a doubt, this was the most demanding genome to date that I have ever sequenced," he says. "With Anzick-1, there was a tremendously low amount of human DNA left — less than 2 percent. The rest was microbial [contamination]."

Although Willerslev is accustomed to sequencing ancient DNA samples in about a year, it took him

FROM TOP: MICHAEL WATERS; SARAH ANZICK; GARY HINCKS/SCIENCE SOURCE



In the Hoyo Negro cave, diver Susan Bird works on the skull of Naia, whose DNA is over 10,000 years old.

PAUL NICKLIN/NATIONAL GEOGRAPHIC

more than three years to sequence Anzick-1's genome because of the DNA's poor condition and his desire to deep sequence the material, repeating the process multiple times for the most accurate results.

Those results were impressive: Anzick-1's genome showed his people were directly ancestral to 80 percent of Native Americans stretching from the Pacific Northwest to southern Chile. And the boy was closely related to the other 20 percent, groups living in Arctic Canada and Greenland.

Meanwhile, in an underwater Mexican cave, the skeleton of a girl, whom researchers call Naia, was revealing secrets of her own.

According to a study published in *Science* in May, the sequencing of Naia's mitochondrial DNA — dated between 12,000 and 13,000 years old — confirmed a shared genetic lineage with modern Native Americans.

Unlike Anzick-1, Naia's remains — the most complete skeleton of an ancient American ever found — include the skull. The teenager, found in the Yucatan Peninsula's Hoyo Negro cave, had a prominent forehead, narrow face and wide-set eyes. These facial characteristics are seen on most of the other ancient American skulls known to researchers but are not associated with modern Native Americans, a disparity that had fueled alternate theories of the continent's first settlers. But Team Naia found no genetic evidence that the girl was related to any other population.

The difference between Paleoamerican and modern Native American facial features is likely a combination of additional waves of migration from Siberia, via Beringia, and genetic drift, a gradual change in appearance and other traits as populations divide, migrate and adapt, says Jim Chatters, a Seattle-area anthropologist who led the multinational study of Naia.

"Anzick and Naia say the same thing, that you have Beringians here very early," Chatters says. "They are two different pieces of a puzzle that's producing one picture."

— GEMMA TARLACH

8

The Year in Fraud



The suicide of a stem cell researcher in Japan last summer prompted a great deal of soul searching in science. Yoshiki Sasai's death came after a scandal involving two papers retracted for fraud — the most high-profile case of scientific misconduct in 2014. But it was far from the only one.

Serious questions were also raised about stem cell research by Harvard's Piero Anversa. We learned more about Cory Toth, a former diabetes researcher at the University of Calgary, whose lab fabricated data in nine published articles. And we saw the discovery of an apparent ring to generate positive assessments, aka peer reviews, of submitted manuscripts, 60 of which wound up being retracted.

It might seem, then, that 2014 was an *annus horribilis* in the world of science fraud. For many in the public, which pays for much of this research in tax dollars, news of these events may have come as a rude awakening. But at Retraction Watch, when we see and hear that kind of commentary, we feel a little like the police captain in *Casablanca* who proclaims he's "shocked, shocked!" to learn there is gambling at Rick's, only to be handed his winnings a moment later.

We started Retraction Watch in 2010, and every year since then, we've witnessed at least a few cases big enough to warrant headlines: anesthesiologist Yoshitaka Fujii, record holder for retractions at 183; Diederik Stapel, whose groundbreaking social psychology work was almost entirely fabricated; Joachim Boldt, the German critical-care specialist and previous retraction record holder. The list goes on.

So what can we learn from all these scandals? Are scholarly journals and their editors, who insist that their peer-reviewed studies are more trustworthy than everything else the public hears about science, little better than carnival barkers hawking bogus trinkets?

The short answer is no. Journals and publishers are, for the most part, doing a good job. They increasingly use software to screen manuscripts for plagiarism, and some even employ statistics experts to review papers for signs of data fabrication. In the Fujii case, for example, the British journal *Anaesthesia* had a stats guru analyze Fujii's articles. His verdict: The chances that the data were valid were infinitesimal.

It's impractical to apply this sort of extensive scrutiny to every one of the nearly 2 million manuscripts submitted each year. But conducting statistical reviews of papers that get flagged during the editorial process — or, perhaps more important, after publication — is an achievable goal, one that would make a significant contribution to the integrity of the scientific literature.

In fact, post-publication peer review is an emerging phenomenon in scholarly publishing. On sites like PubPeer, researchers critique papers, pointing out everything from errors or other problem spots to potentially manipulated images and other evidence of misconduct. One of the reasons there seems to be more fraud is simply that we're better at finding it.

Many scientists, journal editors and publishers have reacted warily to PubPeer and its ilk. Some contend that the anonymity of the post-publication reviewers breeds witch hunts and harms innocent bystanders. But the sites are doing a service by catching horses even though they have already left the barn. In addition, small but growing efforts have also begun, to test whether research holds up by repeating — in scientific parlance, replicating — experiments in cancer and psychology research.

All of these efforts underscore a critical point, one that science may need some time to embrace: The paper is not sacrosanct. It does not come into the world like a flawless, shining deity immune to criticism or critique. If more scientists come to think of a new publication as a larval stage of scientific knowledge and if fewer schools and funding agencies prize the high-profile journal article — basing tenure, grant and promotions on it — then researchers will feel less pressure to cut corners and manufacture dramatic results.

Reporting on cases in which scientists have committed fraud can be disheartening, even heartbreaking. But for every fraudster out there, we know there are dozens of scientists who are quick to correct the record when they discover problems in their work. And they rail against the reluctance of many of their peers to do the same. Sadly, many scientists are worried that acknowledging any fraud in their midst will discourage funding.

We are guided by the old chestnut: The cover-up is worse than the crime. If the growing awareness of an ongoing problem has led to more transparency, the scientific process, and the public who benefits from the knowledge it generates, will be better off. — ADAM MARCUS AND IVAN ORANSKY, CO-FOUNDERS OF RETRACTIONWATCH.COM

KATIE EDWARDS/IKON IMAGES/CORBIS



The "Spinosaurus: Lost Giant of the Cretaceous" exhibition at the National Geographic Museum in Washington, D.C.

First Dinosaur to Menace Land and Water

Uncovered in Saharan Morocco, a new specimen of the dinosaur *Spinosaurus aegyptiacus* helped researchers confirm that the 50-foot carnivore was the largest land predator ever known. And that's probably the least interesting thing about the strange animal; *Spinosaurus* is also the only aquatic dinosaur ever identified.

"*Spinosaurus* breaks the mold. It's not just another *T. rex*-like predator, only bigger," says Nizar Ibrahim, the University of Chicago paleontologist who led the dig. When it comes to its bones, "to be honest, one of the best modern analogs for it is the penguin."

Spinosaurus lived about 95 million years ago in the massive river systems of what's now northern Africa. It was a powerful swimmer, with a crocodilian snout, broad feet that may have been webbed, shortened but heavily muscled hind limbs and a propulsive tail similar to that of some fish.

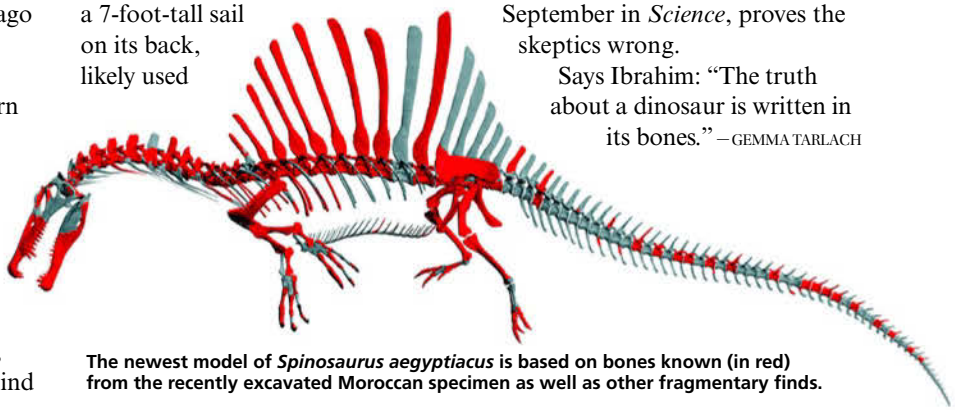
Using CT scans of the new fossil to create a digital model of the dinosaur, Ibrahim and colleagues also discovered that *Spinosaurus* is the only dinosaur that evolved to lose the central cavity in its limb bones. The adaptation, which provides buoyancy control, can be seen today in aquatic animals such as the hippo and, yes, the penguin.

The megapredator also had a 7-foot-tall sail on its back, likely used for display.

Although its anatomy suggests *Spinosaurus* spent at least some time on land, the dinosaur's front-heavy mass and shorter hind limbs meant it had an ungainly, slothlike posture.

The only other partially complete *Spinosaurus* was destroyed during World War II, making study with modern methods impossible. Some paleontologists had doubted the bizarre chimera even existed. The new finding, published in September in *Science*, proves the skeptics wrong.

Says Ibrahim: "The truth about a dinosaur is written in its bones." — GEMMA TARLACH



The newest model of *Spinosaurus aegyptiacus* is based on bones known (in red) from the recently excavated Moroccan specimen as well as other fragmentary finds.

FROM TOP: REBECCA HALE/NATIONAL GEOGRAPHIC; SKELETAL RECONSTRUCTION BY IBRAHIM, ET AL. 2014, SCIENCE/AAAS

10

Quantum Photo Finish

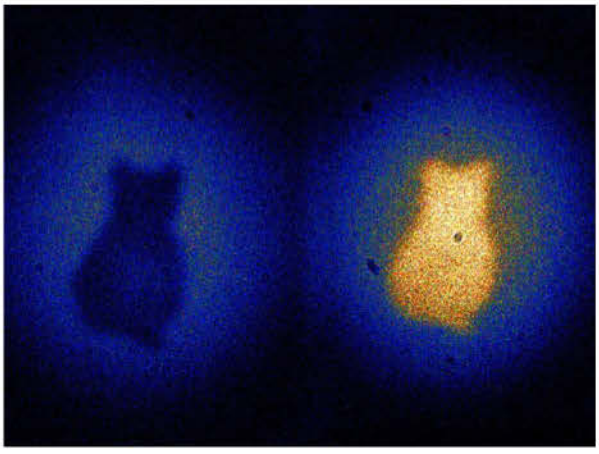
In a dark lab in Vienna, physicists did something incredible: They shined a laser through a cat-shaped hole in some cardboard, resulting in a glowing, red feline image. The twist: The light in the image didn't go through the hole in the cardboard.

The work, published in August, started with a single beam of light. To create a typical image, the entire beam would shine on the cardboard hole. Some light particles, or photons, would pass through, making up an image. The other photons would be blocked.

This time, the physicists took advantage of a weird quantum process called entanglement. Entangled photons are fundamentally linked, carrying some of the same information about each other even after they're separated. Think twins with ESP. "Spooky action at a distance," according to Albert Einstein.

After shining the light beam through a crystal to entangle the photons, the physicists split the beam in two, letting half of each entangled pair pass though the cat cutout. The other half traveled to a detector — a special camera — carrying the cat-shaped information from their twins' journeys.

"I didn't expect the images to come out so well," says physicist Gabriela Lemos, the lead author of the paper.



Images of a cat-shaped cutout created by photons that, due to quantum entanglement, didn't go through the cat cutout.

Interestingly, the twin photons weren't totally identical. The unobserved photons that went through the cat-shaped hole were too low in energy to be visible, while the detected twins were high-energy and visible. The team hopes others can use this unique property to image objects, such as delicate biological samples, that a more energetic, visible beam might otherwise destroy. — SHANNON PALUS



2014 World Debut: **New Species Series**

Amblyopsis hoosieri

Type of animal: Eyeless cavefish

Description: Completely colorless; 2 to 3 inches long; anus on underside of neck

Home: Southern Indiana



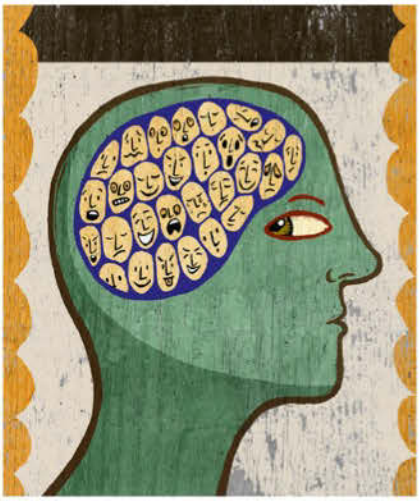
Fun fact: Unlike others of its kind, *A. hoosieri* lacks a debilitating mutation in the rhodopsin gene, which is an important gene for vision. That means it could see just fine … if it had eyes. Researchers named the fish after the Indiana Hoosiers basketball team — but not to imply the players might be visually challenged. The name honors several famous fish scientists who worked at Indiana University, as well as the species's proximity to the university. Plus, the lead author is a Hoosier fan. — BRENDA POPPY

FROM TOP: GABRIELA BARRETO LEMOS; MATTHEW NIEMILLER/ZOOKEYS

Schizophrenia Study Finds New Genetic Links

11

Schizophrenia, which affects 1 in 100 people worldwide and an estimated 2.4 million Americans, exacts tremendous social costs and great human suffering. Drugs can calm the inner voices, delusions and hallucinations, but few patients recover fully, and there is no cure. Nor are there predictive tests or internal markers for the disease — it must be diagnosed by outward signs alone. But this problem is at last yielding to progress on the genetic front.



In July, an international consortium of schizophrenia researchers, mounting what it calls the largest biological experiment in the history of psychiatry, reported 108 regions in the genome associated with schizophrenia. Two dozen of these genetic links had been recorded before, but more than 80 were new. Neuroscientists now have many more avenues for exploring the biological underpinnings of the disorder.

Originally thought to stem from bad parenting, schizophrenia tends to cluster in families, implicating DNA. The risk of the disease rises the closer one is related to a patient. Until recently, gene scans were unsuccessful in turning up links to schizophrenia.

"When we started, we got a lot of things wrong," says Patrick Sullivan, a geneticist and psychiatrist at the University of North Carolina. "We had no clear fix on the problem. What was the best study design? How many samples did we need? Also, in the '80s, genotyping [reading DNA's sequence of letters] was really expensive. Every time a new technology came along, we gave it a shot, but schizophrenia was way more complicated than we thought."

Sullivan is principal investigator for the Psychiatric Genomics Consortium, which includes "nearly everyone in the world who's working on schizophrenia," he says. The consortium's broad-scale analyses included 35 research groups that have integrated genetic samples from a total of 150,000 subjects — 37,000 of whom have schizophrenia and 113,000 healthy controls. The unprecedentedly large sample allows a glimpse of the genetic basis of the disease that smaller, earlier studies didn't have the statistical power to see. The specific method employed was a genome-wide association study, or GWAS.

Because DNA's code varies slightly from person to person, GWAS seeks to identify the places where a schizophrenic's genome differs from a healthy person or from another schizophrenic. The genotyping technology can distinguish a million possible sequences across each sample, the goal being to show the variants that are more prevalent in the patients than in healthy subjects.

The good news from the study was that many of the variants associated with the disorder made biological sense. Some, for example, pointed to genes that expressed themselves in brain cells, or that involved immune function, a previously established connection. Another important hit was at DRD2, the gene for the dopamine receptor, which is targeted by antipsychotic drugs. The bad news — which really wasn't news to the investigators — was that the variants were fairly common in the population, but their effect was weak. They weren't blockbuster genes like those for cystic fibrosis or Huntington's disease, single flaws making for straightforward predictions. The risk of schizophrenia to someone who carries one of these markers is increased by as little as one-tenth of a percent.

Thomas Insel, director of the National Institute of Mental Health, describes schizophrenia as polygenic, meaning that genes probably act in networks to produce it. "The genome works like a symphony, not like a soloist," he says. "If you line up these [variants] and determine the likely function of the genes, do they tell the same story?" The next task will be to engineer neurons in cell cultures so that they manifest one or more of the variants. "Does this alter any aspect of how neurons develop or how they fire?" Insel wants to know.

"The goal of this work is to understand the neurobiology," Sullivan stresses. "So the molecular basis is polygenic. Are we going to sit back and cry because schizophrenia didn't turn out like we hoped it would? It's complicated. That's the scientific challenge." – JEFF WHEELWRIGHT

ILLUSTRATION WORKS/CORBIS

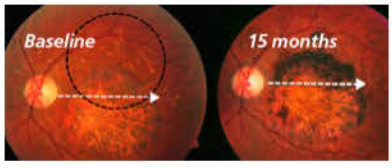
12

Stem Cells Make Insulin, Restore Retinas

Since embryonic stem cells were first cultured in the lab more than 30 years ago, researchers have talked up their therapeutic potential. Able to differentiate into dozens of tissue types, stem cells might be used to regenerate organs and treat numerous diseases.

The proof has been slow to come, however. "You've been hearing about them for decades, but where's the beef?" asks Robert Lanza, chief scientist at Advanced Cell Technology and a pioneer of regenerative medicine. The field has been dogged by political and religious opponents, who object to the destruction of human embryos during the harvest of cells.

So there was extra satisfaction in October when two scientific teams, Lanza's and a group led by Harvard University's Douglas Melton, each announced advances. The group at Harvard's Stem Cell Institute coaxed human embryonic stem cells into pancreatic cells. Transplanted into diabetic mice, the cells secreted insulin and cured the mice in 10 days. The next step — Melton says it's the last hurdle before human trials — will be to shield the foreign cells from rejection by the body's immune system.



Researchers used stem cells to create retinal pigment epithelium cells, which were transplanted into a patient's retina (left) in an area depicted by the black circle. After 15 months, the new cells had grown.

Lanza's therapeutic target has been the eye — specifically, eyes failing from macular degeneration. The study included 18 patients, half with age-related macular degeneration and half with Stargardt's macular dystrophy, the leading causes of blindness in adults and juveniles. From the embryonic stem cells, the researchers produced a type of tissue called retinal pigment epithelium (RPE). Growing RPE cells in quantity, they injected them into one eye of each patient. The subjects were followed for an average of two years.

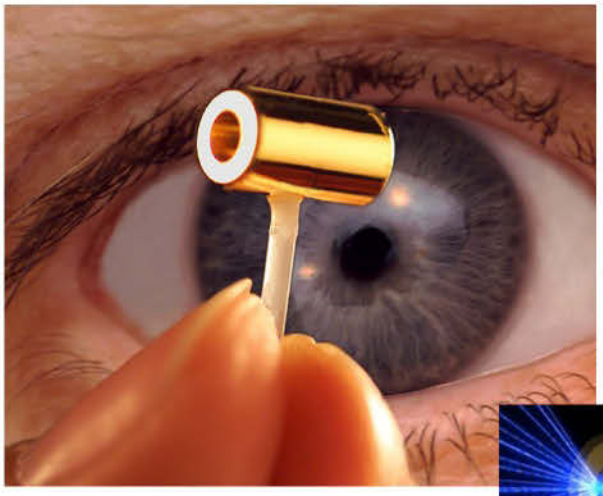
Not only were there no adverse effects from the transplanted cells — this was primarily a safety trial — but 10 patients showed marked improvements in vision, and the eyesight in another seven seems to have stabilized.

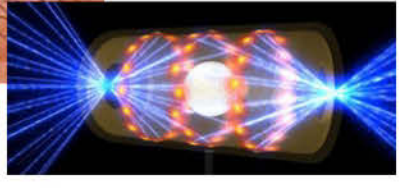
Since it's now possible to reprogram adult cells to make tissues like RPE, Lanza expects the controversy over stem cells to subside. He also plans to use embryonic cell lines "where we extract a cell and don't damage the embryo. We will be able to satisfy all but a small number of people."

— JEFF WHEELWRIGHT

13

A Promising Spark for Lab-Made Fusion





The cylinder (above) that contains the fuel capsule is just a few millimeters wide. A rendering (right) shows the laser beams entering the capsule, where they compress and heat the fuel to trigger nuclear fusion.

In a lab east of San Francisco, physicists trained 192 lasers on a plastic sphere the size of a BB. Inside were ingredients for a powerful fusion reaction similar to the kind that makes our sun hot and glowing.

When they switched the lasers on, the Lawrence Livermore National Laboratory scientists found that more energy came out of the fuel than went in. The research, reported in February, is a crucial milestone toward tapping the power of lab-made fusion.

In fusion reactions, hydrogen isotopes meld together, creating high-energy alpha particles. The key to increasing the captured energy was to keep these particles trapped inside the container, feeding energy back into the reaction.

To make fusion a viable renewable energy source, scientists still have work to do: Some of the lasers' energy was lost before even making it to the tiny bead. The energy produced needs to increase at least a hundredfold for the total energy it takes to turn on a fusion reaction to be less than the total energy gained. Still, this is a spark. — SHANNON PALUS

TOP: STEVEN SCHWARTZ AND ROBERT LANZA. BOTTOM: LAWRENCE LIVERMORE NATIONAL LABORATORY/NATIONAL IGNITION FACILITY (2)



An aerial view of the Colorado River delta as the river once again meets the Sea of Cortez.

A River Resurrected

On May 15, through the window of a propeller plane, conservationist Francisco Zamora witnessed history in the making. Below, he watched a finger of water creep down the dry Colorado River channel and meet the tide in the Sea of Cortez.

It was the first time the 1,450-mile river had been reunited with its natural terminus in more than 60 years (aside from a brief trickle during the unusually wet 1990s). Farms and cities siphon most of the river's water before it reaches Mexico, but on March 23, under a binational agreement, U.S. and Mexican officials unleashed an eight-week "pulse flow" from a small dam on the border to help restore the delta. No one knew, though, whether the water would make it that far downstream.

While the 105,000-acre-foot surge amounted to less than 1 percent of the river's average flow, the ecosystem is showing new signs of life. (One acre-foot of water is enough to supply two homes in the Southwest for about a year.) "The response of the birds is pretty amazing," says Zamora, director of the Sonoran Institute's Colorado River Delta Legacy Program. "Just adding water really enhances the habitat."

Scientists and officials are exploring ways to keep the water coming. "We could potentially reconnect the river with not a lot of water," Zamora says. "The pulse flow showed it can be done." – APRIL REESE





PHOTOS: PETER MCBRIDE. MAP: COURTESY U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION; ROEN KELLY/DISCOVER

15

A Beautiful Find

Mathematicians unlock numerical secrets.

BY **JULIE REHMEYER**



Emory mathematician Ken Ono helped make sense of a long-standing mystery.



LEFT: EMORY UNIVERSITY; RIGHT: THE GRANGER COLLECTION/NYC

Q&A

Last summer, Ken Ono of Emory University became a minor mathematical celebrity when he, along with collaborators Michael Griffin and Ole Warnaar, discovered four infinite families of identities — mathematical formulas involving variables (like x or y) that are true regardless of the values of those variables. (For example, $(a * b)^x = a^x * b^x$.) The new identities are generalizations of two specific ones first found by the great mathematicians Leonard Rogers and Srinivasa Ramanujan in the early 1900s. The finding is a milestone in mathematics.

What led to your interest in the Rogers-Ramanujan identities?

I first learned about them from a famous story. In 1913, the great English mathematician G.H. Hardy received a letter from an unknown, uneducated clerk from India: Srinivasa Ramanujan. Attached were nine pages of mathematical formulas.

A lot of them were well known, and some wrong, but a few were gems, especially two. Hardy said that they must be true because no one would have had the imagination to invent them.

What were these special identities of Ramanujan's?

They're slightly more complicated versions of a beautiful "continued fraction":

First take 1+ 1, or 2.

Next, replace the last 1 with $\frac{1}{1+1}$ to get $1+\frac{1}{1+1}$, or 1½.

Now do it again: $1+\frac{1}{1+\frac{1}{1+1}}$, which gives 1⅔.

If you do that forever, you get the golden ratio, which is defined as: $\frac{1+\sqrt{5}}{2}$

Ramanujan evaluated two other continued fractions in this way. It was largely because of those that Hardy, the professional, and Ramanujan, the amateur genius, ended up collaborating to invent some of the most important mathematics of their day.



Indian mathematical prodigy Srinivasa Ramanujan.

How did Ramanujan come up with those identities that captivated Hardy?

Ramanujan had a secret device: two more identities that he had discovered, which later came to be called the Rogers-Ramanujan identities. He plugged specific numbers into those two identities.

What did you discover about the Rogers-Ramanujan identities?

Griffin, Warnaar and I found a framework that shows why they're true and structurally what makes them tick. They turned out to be two golden nuggets that suggested the existence of a whole mother lode of identities out there. And we showed that they can easily produce numbers mathematicians call "algebraic," which are rare, beautiful numbers akin to the golden ratio.

Why is it important?

The Rogers-Ramanujan identities are tied to a lot of deep mathematics. So this larger framework for them will open up new mathematical territory.

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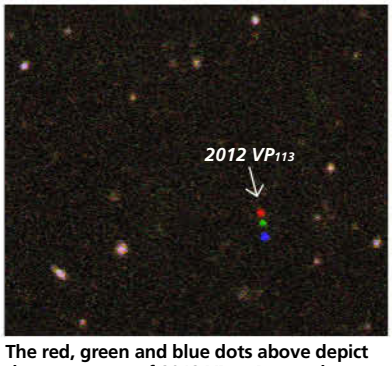
Sedna, shown in this artist's visualization, was once thought to be the only outlier of our solar system. Now 2012 VP_{113} joins it.

New Dwarf Planet Redefines Solar System

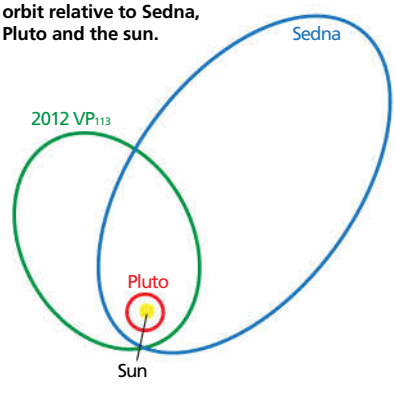
It's not every day we redraw the map of the solar system. With the March discovery of minor planet 2012 VP_{113} orbiting the sun beyond Pluto, astronomers added a new world to the planetary rolls — and redefined the edges of our cosmic neighborhood.

The solar system's farthest major planet, Neptune, is only 30 astronomical units from the sun. (An AU is the average Earth-sun distance, 93 million miles.) Beyond that, at 30 to 50 AU, lies the Kuiper Belt and its minor planets, including dwarf planet Pluto. Before discovering 2012 VP_{113} — soon nicknamed "VP" or "Biden," after the U.S. vice president — astronomers thought only tiny Sedna occupied the empty stretch beyond 50 AU. Now they know it's not alone.

Sedna's perihelion, or closest solar approach, is 76 AU; VP has a perihelion of 80 AU. The newly found world is about 300 miles wide, likely enough for gravity to shape it into a sphere and thus be considered a dwarf planet (though still about five times smaller than Pluto). Its discovery suggests hundreds of similar worlds may lurk in this distant part of the solar system. More tantalizingly, minor perturbations in the orbits of the farthest known objects suggest a massive "super-Earth" major planet might lurk about 250 AU away. — BILL ANDREWS



The red, green and blue dots above depict the movement of 2012 VP_{113}. Researchers added color for visibility. The illustration below shows its orbit relative to Sedna, Pluto and the sun.



FROM TOP: NASA/JPL-CALTECH; SCOTT S. SHEPPARD/CARNEGIE INSTITUTION FOR SCIENCE; ALISON MACKEY/DISCOVER AFTER SCOTT SHEPPARD

The First Designer Chromosome

17

In 2010, geneticist Craig Venter unveiled the world's first synthetic organism — a variant of a bacterium that causes infections in goats. In April, researchers took a step toward a much more useful synthetic microbe, synthesizing from scratch one of the 16 chromosomes of *Saccharomyces cerevisiae*, or baker's yeast.

Yeasts, like humans, are eukaryotes: They have complex DNA packaged in chromosomes and riddled with introns (pieces of DNA that don't contribute to the final protein) and "junk DNA" with no known purpose.

To simplify their task, researchers first searched the computerized genetic code of one chromosome — chromosome 3 — and deleted introns and junk DNA. They added in code to create 98 ready-made cutting sites, like perforations in a sheet of paper, throughout the chromosome. That way, future researchers can pop out various genes and study the effects. Eventually, getting rid of all the non-essential genes would result in a bare-bones yeast with the minimum number of genes possible.

That's important because yeast is a promising workhorse for synthetic biology. A slimmed-down genome will allow all the cell's available energy to go toward producing useful chemicals.

The synthetic chromosome, when inserted into a living yeast cell, functioned just like a normal one. That's good news, but the project to create a fully synthetic yeast genome has a ways to go: Chromosome 3 is just 2.6 percent of the cell's full genetic code.

But would fully synthetic yeast still be yeast at all? Srinivasan Chandrasegaran, one of the authors of the paper in *Science*, takes a pragmatic tack: "As long as it tastes like beer, it's yeast." – LISA RAFFENSPERGER



This synthetic yeast, made of a designer chromosome, is one step toward a fully synthetic version.

TECH APPLICATIONS

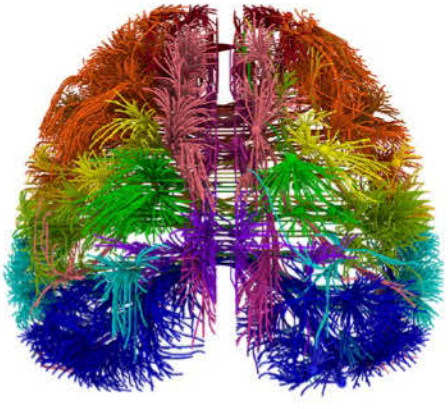
Yeast is already used as a miniature chemical factory in a variety of settings. Custom DNA could make these processes even more efficient.

Artemisinin: Drug manufacturer Sanofi is producing precursors to this anti-malarial drug in genetically modified yeast.

Beer: Brewers today use natural yeasts, but they could eventually design strains to produce exotic beers.

Vaccines: The hepatitis B vaccine is commonly made in modified yeast cells.

Biofuels: Researchers are modifying yeast to produce ethanol and biodiesel.



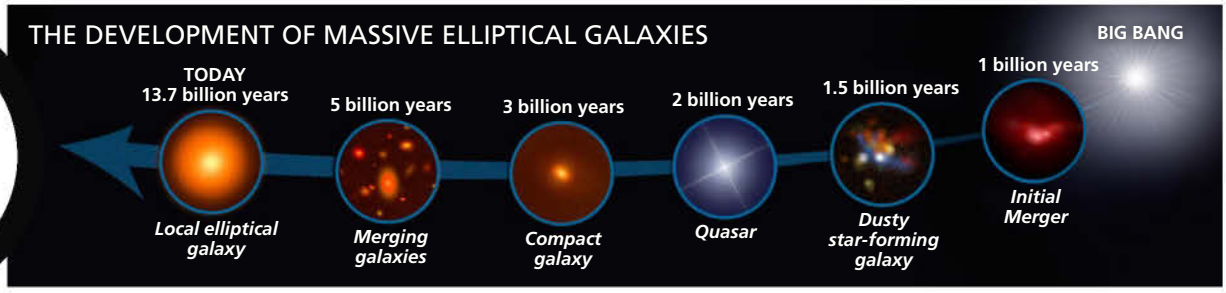
TOP: NYU LANGONE UNIVERSITY SCHOOL OF MEDICINE. BOTTOM: ALLEN INSTITUTE FOR BRAIN SCIENCE

Mouse Brain Mega Map

18

The tiny mouse brain is packed with more than 86 million neurons, each with more than 1,000 connections, clustered into different nodes — similar to a complex highway system. In April, researchers led by Hongkui Zeng of the Allen Institute for Brain Science in Seattle assembled the first road map of neural pathways — called a connectome — inside the mouse brain (left). It's the most comprehensive guide ever assembled of the mammalian brain. Scientists imaged more than 1,700 mouse brains (injected with a tracer virus) at resolutions less than a micrometer, or 50 times smaller than a human hair. They assembled the 1.8 petabytes of data — equivalent to running HD video continuously for 26 years — into a 3-D map. See it at **brain-map.org** – CARL ENGELKING

19



The Lives of the Galaxies

If you'd never met a human, figuring out that babies and seniors are the same species might not be easy. Astronomers have to make such leaps all the time, matching snapshots of youthful galaxies with mature counterparts and filling in missing links.

Take the universe's most massive galaxies — blobby, indistinct ellipticals. Until this year, no one understood how they got so gargantuan. But in January, astronomers used optical and infrared telescopes to look back nearly to the beginning of the universe, just 1.5 billion years after the Big Bang, where they saw newborn ellipticals — ancient galaxies so dusty they're nearly invisible. In their early years, these galaxies formed stars a thousand times faster than the Milky Way does today, eating through their initial gas reserves in just 40 million years. After that, they grew slowly by mating with other galaxies, eventually snowballing into today's mature elliptical galaxies.

Now, 10 billion years later, they don't make new stars at all. Full of old, rose-colored suns, they are "red and dead." Theorists thought they'd become barren in their old age, lacking the cool gas that condenses into new stars. But in February, another team of astronomers discovered that some have plenty of cold gas — they just can't use it. These galaxies' supermassive black holes work against them, devouring nearby gas and exhaling powerful jets that either heat the remaining cold material or push it out of the galaxy entirely.

But not all the news this year focused on ellipticals; spiral galaxies showed up, too. This branch of the galactic family comes in different shapes: Some spirals have flat disks, while others are fat. In February, a third team of astronomers discovered the lifestyle difference: spin speed. As with pizza dough, the faster you twirl it, the thinner the crust becomes. Our own svelte galaxy spins at a speedy 600,000 mph.

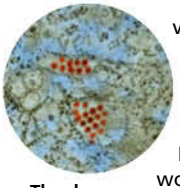
Disks thin out or don't, stars form or don't, and galaxies grow gigantic but geriatric. As any astro-anthropologist would attest, making sense of our galaxy requires making sense of others that are younger, older, fatter, thinner and differently hued. — SARAH SCOLES

20

Dengue Vaccine Clears Major Trial Hurdle

Dengue, known in its most severe form as dengue hemorrhagic fever, is a potentially fatal mosquito-borne infection that afflicts up to 100 million people each year. It's become a leading cause of illness and death in tropical and subtropical regions around the world. But a new vaccine could reduce the disease's reach.

In September, an international research team published much-awaited results of a clinical trial for the vaccine. In the study, which involved 20,875 Latin American children aged 9 to 16, the vaccine's efficacy was 60.8 percent, and it reduced the risk of hospitalization by 80.3 percent. Those results mirrored the findings of a smaller study by the same team published in July that involved about 10,000 children in five Asian countries. In that trial, the vaccine's efficacy rate was 56.5 percent, and it reduced cases of the severest form of dengue by 88.5 percent.



The dengue virus (red) in a tissue specimen.

"This is an incredibly important milestone," says health economist Dagna Constenla of Johns Hopkins University, which is a member of the Dengue Vaccine Initiative, a research collaborative. Scientists have worked on dengue vaccines for years, but this one, created by French drugmaker Sanofi Pasteur, is the first to reach this advanced testing stage.

The virus that causes dengue has four types, and the vaccine appears more effective against some than others. Still, researchers say it holds great promise for combating the disease. Sanofi will seek approval of the vaccine in the next few months, and if all goes well, the drugmaker could begin marketing it by the end of 2015. — CHRISTIE ASCHWANDEN

TOP: NASA/ESA/S. TOFT (NIELS BOHR INSTITUTE)/A. FEILD (STSCI). BOTTOM: ROBIN TREADWELL/SCIENCE SOURCE



21

Heavyweight Dino of the World

After four years of excavation and five years of study, *Dreadnoughtus schrani* debuted in September as a top contender for the largest land animal ever: 65 tons and 85 feet long, with a 37-foot neck and muscle-bound 30-foot tail.

Paleontologist Kenneth Lacovara first spotted just a small patch of exposed bone one morning in February 2005 in Argentine Patagonia. Lacovara and fellow Drexel University researchers quickly returned, and by nightfall they had uncovered a 6-foot-long femur. "We knew immediately that we were looking at one of the largest known dinosaurs," says Lacovara.

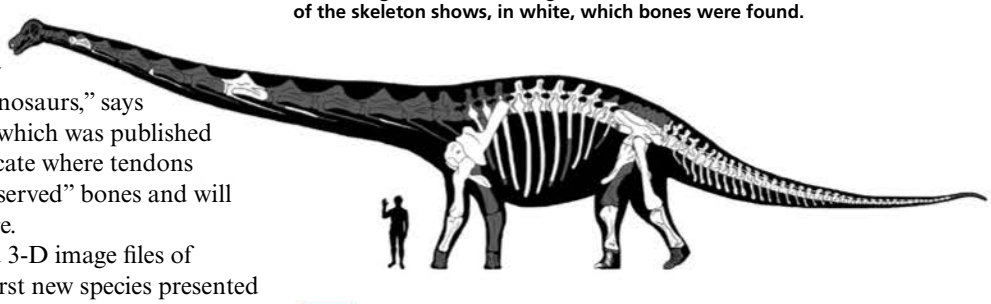
Dreadnoughtus lumbered through fern-filled forests between 66 million and 85 million years ago, and it left an astonishingly complete fossil: Almost half of the bones, 145, were recovered. *Argentinosaurus*, presumed to be the largest titanosaur, is known based on just 13 bones.

"Until *Dreadnoughtus*, we could only guess at the body proportions of supermassive dinosaurs," says Lacovara, author of the study, which was published in *Scientific Reports*. Scars indicate where tendons attached to the "exquisitely preserved" bones and will allow analysis of its musculature.

The Drexel team has released 3-D image files of *Dreadnoughtus*, making it the first new species presented along with its open-access virtual skeleton. "Any scientist or kid in the world can, to a substantial degree, see just what we were seeing," Lacovara says. —ERIK NESS



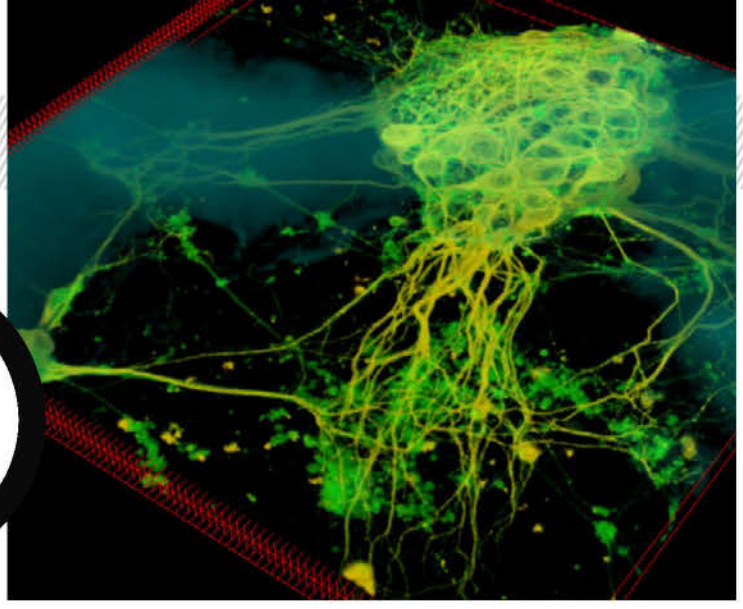
Kenneth Lacovara stands amid the skeleton of the massive *Dreadnoughtus schrani* in Argentina. Below, a reconstruction of the skeleton shows, in white, which bones were found.



To download 3-D image files of the *Dreadnoughtus* discovery, go to **tinyurl.com/Dreadnoughtus-images**

FROM TOP: JENNIFER HALL; COURTESY KENNETH LACOVARA; LACOVARA, ET. AL.

22



The Best Brain Model Yet

One little doughnut — a lab-engineered protein doughnut — could help researchers cure Alzheimer's and Parkinson's and restore a traumatized brain. In August, scientists at Tufts University unveiled a new 3-D human brain "doughnut" model that accurately imitates brain function and injury response.

David Kaplan and his team built their model by constructing a collagen gel-filled protein ring that cultures rat neurons. Unlike older, simpler models, this one's compartmentalized architecture (indicated by the multicolored rings) simulates the regions of the brain, and the chemically neutral protein allows neurons to connect realistically.



These multicolored protein ring doughnuts (above) mimic brain regions. The doughnut sustains neurons (top) for months, longer than any other brain model.

After growing the model for two months — previous ones lasted a few weeks at best — the team dropped different weights on the system to simulate brain trauma, like a concussion. Amazingly, all measured responses mimicked a human brain, making it the most realistic, responsive 3-D human brain model to date. And its longevity will allow researchers to introduce diseased cells to the model to better understand how brain diseases play out over time.

Although it's impressive, the model has limitations. It absorbs oxygen and nutrients through cell membranes, not blood vessels, shortening its life span. Researchers want to integrate a humanlike vascular component to "feed" the model and extend its already superior life span. — KATIE BO WILLIAMS

23

Freezing Light in Its Tracks

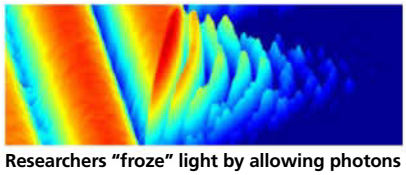
Light is thought to be the fastest stuff around, zipping so speedily through the universe that, even if it were tangible, you probably couldn't pin it down. But in September, physicists reported the seemingly impossible: They froze light into a crystal-like state.

Light particles, or photons, normally interact only with matter, not each other. But Princeton physicist Andrew Houck and colleagues built a device that effectively lets one photon trade energy with another, putting them in a crystal-like state. The device, about ¼ inch across, sounds simple: two tiny wires bridged at one end by a capacitor, with the other ends plugged into photon generators. The team first shot photons into the wires while blocking their exit with two-way mirrors, and the photons behaved normally, bouncing freely back and forth between the wires.

But when Houck's team added a tiny piece of supercooled aluminum near the ends not connected by the capacitor, they observed some odd effects. Because of the quirks of quantum physics (the unintuitive rules governing physical action, including that of particles, on the smallest of scales), the aluminum acted as a messenger between photons sent in the wires, imparting subtle changes on the photons with each bounce past it.

Eventually, the photons' energy levels changed so much that it took more energy to jump between wires than to stay put. When that happened, the photons froze in place on one of the wires, like water molecules losing heat until crystallizing into ice.

This frozen state — intangible and invisible to human eyes — is a brand-new behavior for light. And Houck is planning a bigger device with 200 wires. Such a system may help scientists understand matter's behavior when it gains or loses mass or energy. In other words, freezing photons could help shed light on the material world. — NEIL SAVAGE



Researchers "froze" light by allowing photons to interact with each other and lose energy, like water molecules losing heat and freezing.

COUNTERCLOCKWISE FROM TOP: DAVID KAPLAN/TUFTS UNIVERSITY (2); COURTESY JAMES RAFTERY AND ANDREW HOUCK/PRINCETON UNIVERSITY

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Chemical Spill Exposes Federal Loophole







Clockwise from top: Crude MCHM contaminated the Elk River in Charleston, W.Va., in January, after a storage tank ruptured at Freedom Industries. Many rallied at the state Capitol to demand safety measures, while area residents had to rely on bottled water for weeks.

Before 10,000 gallons of an obscure coal-processing chemical spilled into the Elk River near Charleston, W.Va., in January and contaminated water supplies for more than 300,000 residents, few people knew crude MCHM existed. The chemical isn't listed in the EPA's public database of toxic chemicals, and it's not federally regulated. Suddenly, the licorice-pungent compound was in the spotlight as the star of one of the worst water contamination episodes in U.S. history. But whether new safety measures for crude MCHM — and thousands of other unregulated industrial chemicals — will now take center stage remains unclear.

Crude MCHM, or 4-methylcyclohexane methanol, is used to purge impurities so coal burns more cleanly. But the cleaner itself is not so clean. As the compound flowed from a ruptured storage tank and its cracked containment pond at Freedom Industries' Etowah River Terminal — just 1.5 miles upstream from a drinking-water intake — hundreds of Charleston residents crowded hospital emergency rooms reporting nausea and other ailments.

At first, the Centers for Disease Control and Prevention said the contaminant posed little risk to public health, because concentrations of crude MCHM were measured at less than 1 part per million. But six days later, officials changed course, warning that pregnant women, children and other vulnerable residents should keep the taps turned off.

The confusion exposed a long-standing blind spot in U.S. environmental policy: Thousands of industrial chemicals lack sufficient health and safety information. That's because of a loophole in the 1976 Toxic Substances Control Act, which exempted chemicals already in use when Congress passed the law. At the time, officials presumed they were safe.

"This particular chemical is an example of tens of thousands of chemicals that are widely in commerce, but for which we know very little about their toxicology," says epidemiologist Lynn Goldman, who headed the EPA's toxic chemicals division in the 1990s and is now dean of public health at George Washington University.

As the chemical snaked through Charleston's water pipes, the CDC tracked down a single MCHM study, conducted by Eastman Kodak in 1990 to assess the risk to workers.

But the study, performed on rats, only examined short-term risks such as skin or eye irritation, Goldman notes. It wasn't designed to consider effects on public health.

A federal bill to close TSCA's loophole hasn't gotten very far. But a state measure to strengthen storage tank rules passed the West Virginia Legislature in the spring.

While the cleanup continues, public concern lingers. Four months after the spill, about two-thirds of residents said they still weren't drinking from the tap, according to a local health department survey. —APRIL REESE

FROM TOP: TYLER EVERT/ASSOCIATED PRESS/CORBIS (2); JAMES FASSINGER/CORBIS; JOHN RABY/ASSOCIATED PRESS/CORBIS

Diamonds Reveal Hidden 'Oceans' in Earth's Mantle

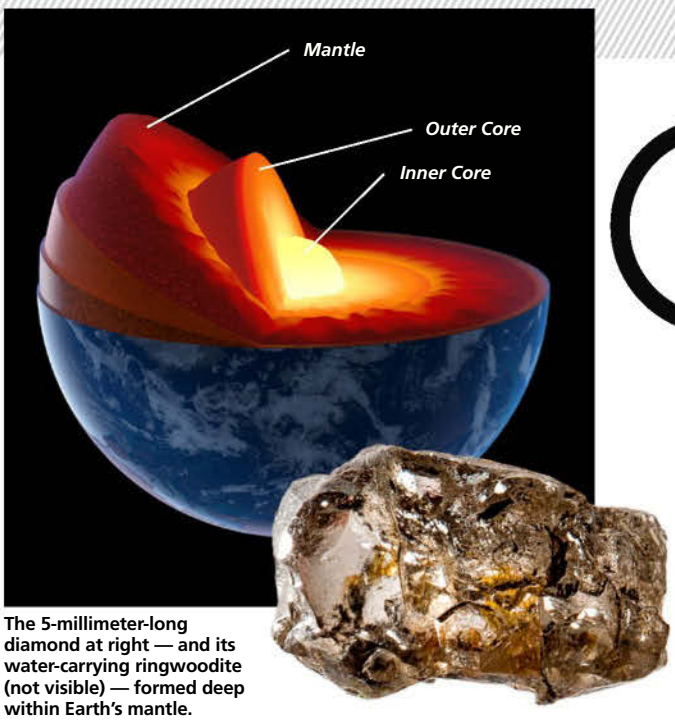
A tiny diamond weighing less than 1/200th of an ounce makes for a puny engagement ring, but what it tells geologists is priceless: Vast quantities of water might lurk unseen deep within the hot, thousand-degree confines of Earth.

In 2009, Canadian geochemist Graham Pearson and his graduate student John McNeill were analyzing a pile of diamonds that formed at least 325 miles underground hundreds of millions of years ago. After emerging through a volcanic explosion, the diamonds were found in 2008 at the edge of the Amazon rainforest. McNeill and Pearson were studying them to look for clues about the evolution and origin of the mantle, the thickest of Earth's inner layers.

After shining a laser into hundreds of diamonds, probing their composition, McNeill spotted something he hadn't seen before: a speck of a mineral called ringwoodite. Though thought to be plentiful in the planet's deep, high-pressure interior, scientists had previously seen the mineral only in meteorites, or synthesized in labs.

Within that speck of ringwoodite, it turned out, was something stranger: a tiny bit of water, trapped and distributed microscopically in the mineral during its formation. Pearson completed a detailed analysis of the diamond this year, confirming the water's discovery.

Finding direct evidence of a watery underworld "was a huge piece of luck," says Pearson. And that world could be very watery. The mantle is vast, and each speck of ringwoodite within it could contain water — potentially enough to rival the water in Earth's oceans. — SHANNON PALUS



The 5-millimeter-long diamond at right — and its water-carrying ringwoodite (not visible) — formed deep within Earth's mantle.

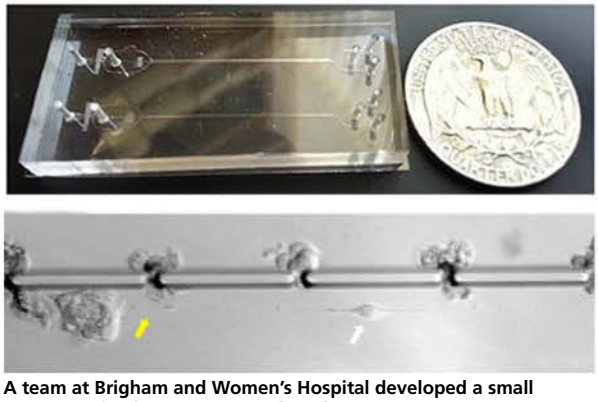
25

Platelet Production, Pumped Up

More than 2 million units of platelets — the blood cells responsible for clotting — are transfused each year, with cancer patients receiving an important share of them. However, donors alone can't possibly meet the need; platelets have a shelf life of only five days, and by 2019, demand will exceed supply by 533,000 units.

To ensure a steady, contaminant-free and abundant supply, in July Jonathan Thon's team at Brigham and Women's Hospital in Boston reported devising a bench-top "bioreactor on a chip." About the thickness of a quarter, the bioreactor "reproduces the physiology of bone marrow," says Thon.

When cells called megakaryocytes — derived from human stem cells — are pumped into the device and subjected to forces mimicking blood flow, they respond by making platelets. Next, Thon hopes to scale up the bioreactor to produce enough platelets for human trials. "It's not enough to make a lot of platelets," he says. "They need to be safe to go into people." — JEFF WHEELWRIGHT



A team at Brigham and Women's Hospital developed a small bioreactor (top) that can make fully functional human platelets. Artificially induced stress forces cells called megakaryocytes through tiny gaps (above) in the bioreactor's central channel. The cells squeeze through the gaps (yellow arrow) and break free (white arrow), forming platelets.

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FROM TOP: JOHAN SWANEPOEL/SHUTTERSTOCK; RICHARD SIEMENS/UNIVERSITY OF ALBERTA; JONATHAN THON; BLOOD: JOURNAL OF THE AMERICAN SOCIETY OF HEMATOLOGY, JULY 21, 2014

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New Chronology for Old Mummies





Funerary wrappings (above, right) from a 1920s excavation (left) suggest mummification is older than scientists thought. Analysis of the wrappings pushes the practice's timeline back nearly 1,000 years.

After sitting unnoticed for nearly a century, a handful of artifacts is rewriting ancient Egyptian history.

Egyptologists previously dated mummification's beginnings to the Old Kingdom period, about 2500 B.C. However, after conducting the first successful chemical analysis of linen used in Neolithic burials, researchers announced in August they had discovered that people living in what is now Egypt were mummifying their dead much earlier — as far back as 4300 B.C., more than a millennium before the establishment of the Egyptian state.

It can be difficult to find material that is reliably documented from pre-Dynastic Egypt, but textile expert Jana Jones of Australia's Macquarie University managed to identify the perfect specimen at the Bolton Museum, north of Manchester, England: fragmentary funerary wrappings more than 6,000 years old, collected in the early 20th century from a region of Upper Egypt.

After isolating material coating the textile fragments, University of York archaeological chemist Stephen Buckley analyzed its chemical makeup. He confirmed the substance was a man-made preservative and that it was virtually the same as compounds used at the height of the era of pharaohs.

"The surprise was that the recipe was so similar — both the constituents and the relative proportions — to what was used 3,000 years later," Buckley says.

Another surprise: Chemical signatures of some of the ingredients revealed they came from as far away as Turkey. The find suggests that Neolithic Egypt, generally seen as a disorganized society, was far more advanced and engaged in long-distance trade.

"It changes our understanding of the entire culture," Buckley says. "It shows they had an understanding of empirical science. Culturally, they were fairly sophisticated, and they were going to huge efforts to get these materials from the northeast Mediterranean to stick on a dead body." — GEMMA TARLACH

CLOCKWISE FROM LEFT: G. BRUNTON, MOSTAGEDDA AND THE TASIAN CULTURE (LONDON 1937) PL. VI; RON OLDFIELD AND JANA JONES (2)

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Bionic Blood Sugar Control

For 14 years, ever since his son was an infant, Edward Damiano has worriedly checked on David as he slept. David has Type 1 diabetes and cannot regulate his blood sugar. His pancreas fails to produce and release two hormones: insulin, which lowers glucose levels in blood, and glucagon, which pushes glucose back up again. Despite insulin injections and regular monitoring, diabetics are whipsawed between extremes: High blood sugar degrades their organs over the years, while low blood sugar at any time can be fatal. Damiano feared that David could die of severe hypoglycemia in his sleep, what parents of diabetic children sometimes call "dead in bed syndrome."



Edward Damiano (right) helps his son, David, with his math homework.

An associate professor of biomedical engineering, Damiano was in a position to help his son. "Years ago," he says, "I started thinking about a two-hormone system that would make automatic therapeutic decisions."

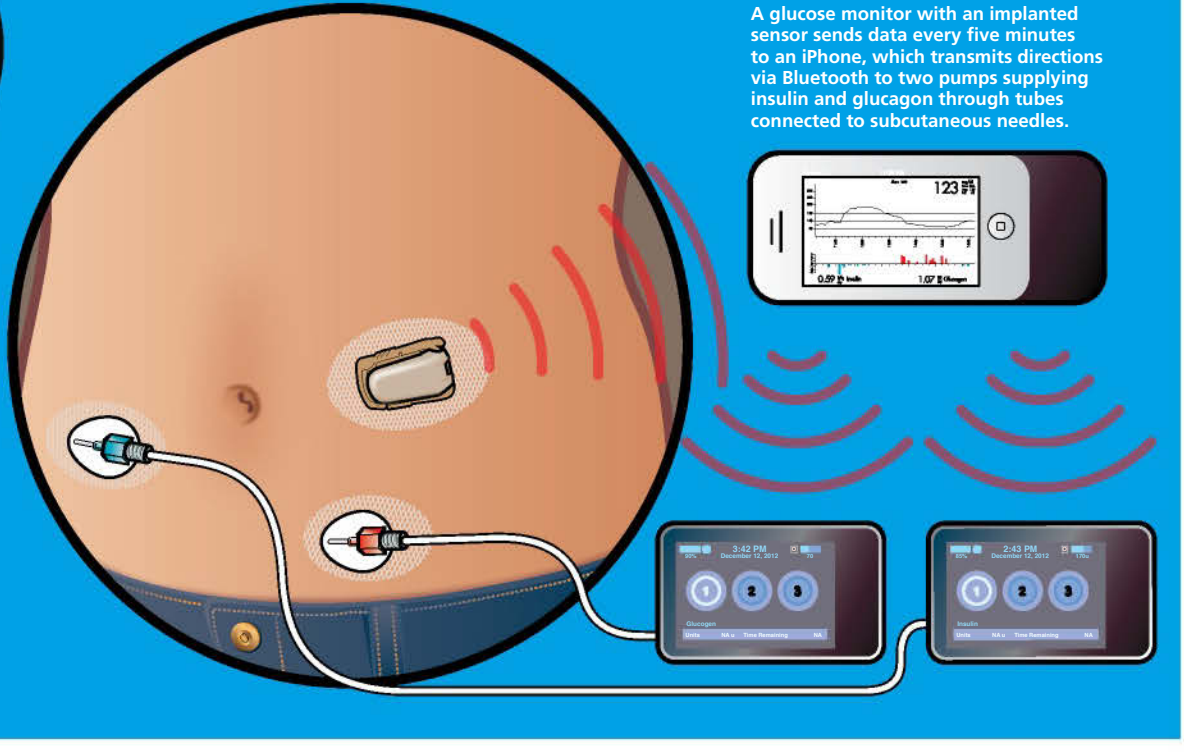
In June, Damiano's team of doctors and engineers at Boston University and Massachusetts General Hospital demonstrated that system, the so-called bionic pancreas. It consists of a glucose monitor, which checks the blood sugar via a sensor under the skin, and two pumps, also connected to the patient, one supplying insulin and the other glucagon. The control center in the prototype is a modified iPhone that wirelessly tells the pumps how to respond to shifts in glucose. "It makes adjustments every five minutes, 288 times a day," says Damiano. The components all fit into a fanny pack or coat pocket.

In trials involving two groups of diabetic patients, adults and adolescents, the bionic pancreas provided tighter control of blood glucose than standard measures such as insulin pumps and blood-sugar monitors.

The team's goal is to submit an updated device for FDA review in 2016. Damiano made a bet with himself that a final version of the apparatus would be ready by the time David goes to college. How soon is that? "Thirty-three months," he says. —JEFF WHEELWRIGHT

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HOW THE BIONIC PANCREAS WORKS



TOP: ELLEN WEBBER. BOTTOM: JAY SMITH

29



Two views of the Laser Weapons System, developed by the U.S. Navy and deployed in the summer on the USS *Ponce*.



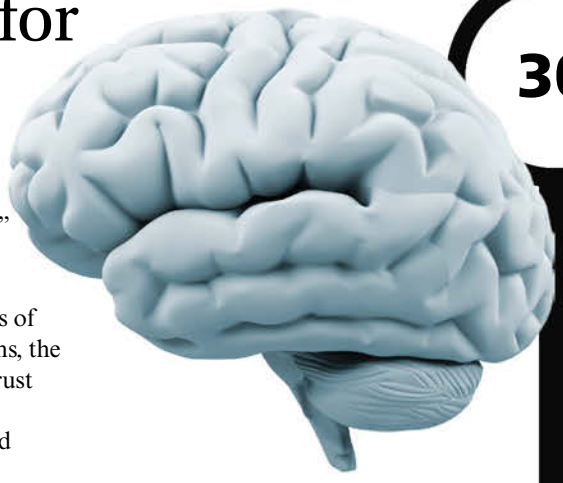
Navy's First Laser Weapon Ships Out

The U.S. Navy turned science fiction into reality over the summer by deploying its first laser beam weapon on the USS *Ponce*, a transport ship. The solid-state Laser Weapons System blasts targets with an energy beam that's concentrated enough to set drones and small enemy boats ablaze. The weapon uses just 30 kilowatts of energy per shot, which means it's also cost effective. (A clothes dryer uses about 3 kilowatts per load.) "You're getting shots for less than a dollar, as opposed to ammunition, which can cost hundreds of dollars per round," says Navy Cmdr. Vince Chernesky. —CARL ENGELKING

LEFT COLUMN: NAVY PHOTOS BY JOHN F. WILLIAMS; RIGHT COLUMN FROM TOP: ANNTSHUTTERSTOCK; KYUNG-SUK KIM AND MAZEN DIAB/BROWN UNIVERSITY

30

New Math for Designer Wrinkles

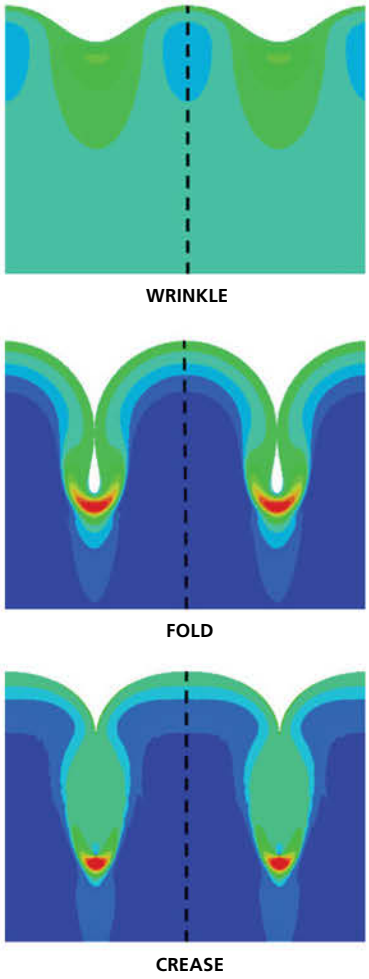


"Folds are everywhere," says Kyung-Suk Kim, an engineer at Brown University. They're in the wings of insects, the surface of our brains, the fabric of umbrellas, even the crust of the Earth.

In June, Kim's team reported the first general mathematical description of how the surfaces of common rubbery materials fold. Imagine laying a sheet of paper flat on a table, then squeezing it together from both ends. First, it begins to wrinkle: Little waves form on the surface, with rounded peaks and U-shaped troughs. As you squeeze it more, the wrinkles accumulate, and the U-shaped troughs compress until two tips of each U touch. With still more force, the lower part of each U collapses, forming creases.

By analyzing these states — called "ruga" states from the Latin word for "wrinkle" — Kim and postdoc Mazen Diab developed a series of customizable equations that allows researchers to calculate, from the stiffness of a material, how much it must be compressed to wrinkle, fold or crease. The equations also predict how hard they must pull the sheet to unfurl the material.

The new equations could shed light on how brain tissue compresses during a head injury, as well as enable a vast array of engineering applications, including creating hairpin-shaped crinkles in thin materials to control liquids on tiny devices; building wearable gadgets that stretch and wrinkle just so; making ultrathin electronics that are resistant to harmful creases; and more. To control folds is to control the critical nooks and crannies of the world. —SHANNON PALUS



Surefire wrinkles: New mathematics lets scientists predict how squeezing a rubbery material causes its surface to deform. First, the surface forms wavelike wrinkles (top), then loose folds (middle) and, finally, tight creases (bottom).

31



Asteroid Rocks the Rings

Rings are common sights around the four largest planets of the solar system, but astronomers reported in March that they had found the celestial circles around an unexpected and much smaller fifth target: an asteroid named (10199) Chariklo. The space rock is just 154 miles wide, yet when it passed in front of a distant star, two delicate, icy rings clearly stood out. One is about 4 miles wide, the other 2 miles, and a 6-mile gap separates them from each other. The illustration above shows Chariklo's surface and the sun behind the rings, which might have arisen from a collision that once rocked the asteroid. —BILL ANDREWS



The asteroid named (10199) Chariklo is the smallest known object to sport a set of rings.

32

Next-Gen Sound Capture Is in the Bag

"Mary Had a Little Lamb" has once again made aural history. More than 130 years after Thomas Edison shouted the song to his tinfoil phonograph, making the first human voice recording, researchers from MIT, Microsoft and Adobe recorded the rhyme using the world's first "visual microphone" — an empty bag of potato chips.

Just as a song's bass thumps in your chest at a concert, Mary's lamb caused minute vibrations — just tenths of a micrometer — in the chip bag. While our eyes can't see the tiny vibrations, the team's high-speed camera, placed behind soundproof glass, could. By analyzing only the bag's tiny shakes, they reproduced the whole rhyme, the scientists announced in August.

Theoretically, with most cameras and this general technique, you could leave Doritos in your friend's room and find out what people are saying about you. Police could one day comb security camera footage and identify a perp by how his voice gonged against a glass of water. But the technique's most valuable application will likely be using sound to probe the structural properties of objects — studying metal alloys, for instance, by blasting sound at them.



By filming the vibrations of a bag of chips, scientists can now re-create ambient sound.

The visual microphone turns the world into an even more data-rich place, ready to be mined, according to lead scientist Abe Davis. "We've shown that video, which is everywhere today, contains all this information that we didn't know was there," he says. "It adds a new dimension to the way we can image the world." —SARAH SCOLES

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FROM TOP: ESO/L. CALÇADA/M. KORNMESSER/NICK RISINGER/SKYSURVEY.ORG (2); ABE DAVIS, ET AL./MIT

Japan's 'Scientific' Whaling Program Harpooned by U.N. Court

Critics have long argued that Japan's "scientific research" whaling was commercial hunting cloaked in a lab coat. In March, the United Nation's International Court of Justice agreed: It ordered Japan to halt its annual hunt off Antarctica. But the ruling may be only a temporary setback for the Land of the Rising Sun.

The International Whaling Commission imposed a moratorium on commercial whaling in 1986, but it allowed the killing of some whales for scientific research. Since then, Japanese harpooners have caught 10,710 Antarctic minke whales in the Southern Ocean around Antarctica, a whale sanctuary. Japan claimed the kills were necessary to study recovering populations, but the court said they were excessive.



Japanese whalers cut up an Antarctic minke whale, one of 10,710 killed under a 1986 research loophole.

Japan isn't likely to put away its harpoons, though. Japanese officials say they plan to redesign their research program to align with the commission's rules.

"I would bet the farm that whaling will continue in the future much as it has, albeit with some flimsy window dressing to make it look like they're complying with the spirit of the ruling," says whale researcher Phillip Clapham of the National Marine Mammal Laboratory.

If Japan — the only nation using the loophole — submits an acceptable proposal to the commission, the country could resume the practice as soon as November 2016.

—SUSAN MORAN

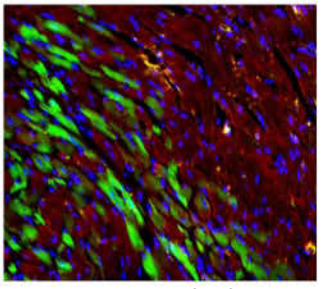


This 1993 photo of a crew tying up minke whales during a Japanese "research" expedition helped spark a global outcry and court action.

TOP: PAUL ENSOR/HEDGEHOG HOUSE/MINDEN PICTURES/CORBIS. BOTTOM: MARK VOTIER/HULTON ARCHIVE/GETTY IMAGES

34 Heart Cells Transformed Into Pacemakers





Eugenio Cingolani, left, of the Cedars-Sinai Heart Institute and his colleagues used a gene to spur typical heart cells to become specialized pacemaker cells, shown above in green.

About 700,000 times a year, surgeons slice a pocket into someone's chest, implant a battery-powered device and thread electrical leads into the heart. Such pacemakers allow malfunctioning hearts to beat steadily, keeping patients alive.

But in rare cases, the devices can cause infections when implanted, and batteries don't last forever. What if the body could be coaxed into making new pacemaker cells to replace those destroyed by age, disease or damage?

Researchers took a step in that direction by using a cold virus to deliver a gene into the heart of a living pig. Once there, the gene transformed a few typical heart cells into specialized pacemaker cells. The genetically improved hearts not only beat properly, but the pigs were more active, suggesting that they felt better, too, says Eugenio Cingolani of the Cedars-Sinai Heart Institute in Los Angeles. He and colleagues reported the finding in July in *Science Translational Medicine*.

Such biological pacemakers could eliminate the need for the devices and the leads, which can become infected or damaged, requiring doctors to remove the pacemakers. The special cells also would eliminate additional surgeries for younger adults and children with congenital heart defects, who need new pacemakers as they grow.

Pacemaker cells could eventually help the most vulnerable patients of all: those who haven't yet been born. Now, fetuses with heart rhythm problems have to wait until birth to get a pacemaker — if they live that long. The new technique could offer the potential for treatment in utero. — KAREN WEINTRAUB

35 Prevalent Pesticide Linked to Bird Decline

News flash! Insecticides harm birds, according to a pioneering book published — oh, back in 1962.

Silent Spring was biologist and writer Rachel Carson's call to arms for the nascent environmental movement, and it led to bans on organochlorines like DDT. But, in a case of déjà vu all over again, scientists have now linked some of today's most widely used pesticides — a class called neonicotinoids — to worrisome declines of farmland birds.

Previous studies linking neonicotinoids to sharp declines in honeybee populations, known as colony collapse disorder, prompted the European Union in 2013 to pass a two-year ban on the use of the pesticides, though bee experts now believe a parasitic mite, poor nutrition or both may also weaken or kill the insects.



Farm insecticides may leave young barn swallows without enough food.

The worrisome study of birds, published in July in the journal *Nature*, focused on the effect of imidacloprid, the most popular neonicotinoid, on 15 species. Researchers from Radboud University in the Netherlands found that in the two decades since Dutch farmers began using the pesticide on a variety of crops, the birds' population declined by an average of 3.5 percent annually in farmlands where local water levels contained high concentrations of the chemical.

The researchers theorize that the decline is occurring not because the birds ingest imidacloprid, but because the pesticide wipes out the insects that nine of the 15 bird species rely upon for food.

Although the researchers cautioned that more study is needed, they urged lawmakers in the meantime to "take into account the potential cascading effects of neonicotinoids on ecosystems."

— DAN HURLEY

TOP: CEDARS-SINAI HEART INSTITUTE (2). BOTTOM: MICHAEL DEFREITAS/ROBERT HARDING WORLD IMAGERY/CORBIS

Doctor ***Designed.*** Audiologist ***Tested.*** FDA ***Registered.***

Affordable *New* Digital Hearing Aid *Outperforms* Expensive Competitors Delivers *Crystal -Clear* Natural Sound

Reported by J. Page

Chicago: Board-certified physician Dr. S. Cherukuri has done it once again with his newest invention of a medical grade ALL DIGITAL affordable hearing aid.

This new digital hearing aid is packed with all the features of $3,000 competitors at a mere fraction of the cost. Now, most people with hearing loss are able to enjoy crystal-clear, natural sound—in a crowd, on the phone, in the wind—without suffering through "whistling" and annoying background noise.

After years of extensive research, Dr. Cherukuri has now created a ***state-of-the-art*** digital hearing aid that's packed with the features of those expensive $3,000 competitors – at a ***fraction of the price***.

New Digital Hearing Aid Outperforms Expensive Competitors

This sleek, lightweight, fully programmed hearing aid is the outgrowth of the digital revolution that is changing our world. While demand for "all things digital" caused most prices to plunge (consider DVD players and computers, which originally sold for thousands of dollars and today can be purchased at a fraction of that price), the cost of a digital medical hearing aid remained out of reach.

Dr. Cherukuri knew that many of his patients would benefit but couldn't afford the expense of these new digital hearing aids. Generally they are not covered by Medicare or most private health insurance.

The doctor evaluated all the high priced digital hearing aids on the market, broke them down to their base components, and then created his own affordable version—called the **MD**HearingAid®***AIR*** for its virtually invisible, lightweight appearance.

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Proudly assembled in the USA from Domestic & Imported Components.

BBB RATING A

- ✓ Nearly *invisible*
- ✓ *Crystal-clear* natural sound
- ✓ No suffering with *'whistling'* or background noise
- ✓ *Outperforms* $3,000 models
- ✓ Amazing *low price*

Affordable Digital Technology

Using advanced digital technology, the **MD**HearingAid®***AIR*** automatically adjusts to your listening environment—prioritizing speech and de-emphasizing background noise. Experience all of the sounds you've been missing at a price you can afford. This doctor designed and approved hearing aid comes with a full year's supply of long-life batteries. It delivers crisp, clear sound all day long and the soft flexible ear buds are so comfortable you won't realize you're wearing them.

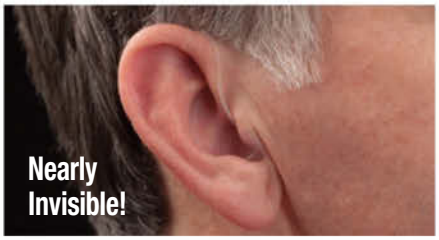
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Of course, hearing is believing and we invite you to try it for yourself with our RISK-FREE 45-day home trial. If you are not completely satisfied, simply return it within that time period for a full refund of your purchase price.

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"I recently purchased an MDHearingAid AIR for both ears. They are as small and work as well as a $5,000 pair I had previously tried."

— Dennis

"I'm a physician, and this product is just as effective (if not more) than traditional overly-priced hearing aids. I will be recommending (it)."

— Dr. Chang

"As a retired advanced practice nurse, I purchased the MDHearingAid AIR after the Wall Street Journal *review. I am so pleased with the quality. You are providing a real service to our affordable health care."*

— Ned Rubin

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36 A Pint-Size Polar Predator



Nanuqsaurus hoglundi was the big little dinosaur find that nearly got left behind.

Classified in a March study, the hobbit *T. rex*, barely two-thirds the size of its more famous relative, roamed the Arctic some 70 million years ago. It's the only tyrannosaur ever found outside temperate latitudes, rewriting our understanding of the animals' diversity.

"I recall just hoping I'd remember to put those rocks on the helicopter," says Anthony Fiorillo, curator of Earth sciences at the Perot Museum of Nature and Science in Dallas.

In 2006, Fiorillo's team was above the Arctic Circle, on Alaska's North Slope. The polar season for fieldwork is brief, and they were busy excavating horned dinosaurs. But they also noticed a few interesting-looking, basketball-size rocks lying around the site. Fiorillo set them aside, thinking he would take them if the helicopter had room. It did.

Paleontologist Ron Tykoski looked at the rocks when they arrived at the Perot a few months later with 11,000 pounds of other material from the Alaskan dig. "I realized, hey, that's a skull with sharp, pointy teeth. That's a predator," says Tykoski.

But he was focused on the 4-ton horned dinosaur *Pachyrhinosaurus perotorum*. After a cursory examination, he decided the predator was probably closely related to *Albertosaurus*, a bipedal carnivore, and he set the rocks aside.

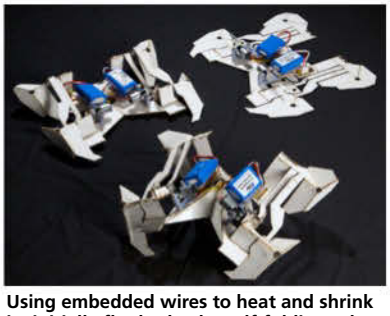
Yet as the researchers continued working, they noticed something. "We were finding isolated teeth with the horned dinosaur bones, even scoring on the bones, and started wondering, 'Who's eating our horned dinosaur?'" says Fiorillo.

The team took another look at those basketball-size rocks. The teeth found in the rocks were consistent with those that had once sunk into *P. perotorum*. Inspecting the fragments of skull, jaw and teeth more closely, they realized they had a tyrant on their hands.

Although short stuff compared with *T. rex, N. hoglundi* was still formidable, about 25 feet from teeth to tail. Its shrunken size may have been an adaptation to survive the long polar winter, when months of near or total darkness meant limited hunting opportunities.

—GEMMA TARLACH

37 Origami Robots Enter the Fold



Using embedded wires to heat and shrink its initially flat body, the self-folding robot is ready to scuttle away in just minutes.

At first glance, it looks like a child's science fair project: a flat, plastic cutout with batteries in the middle. Then it shudders to life. A few joints bend. The midsection rises with a startling jolt. Moments later, it scuttles away.

This crab-walker — which self-assembles from about $20 worth of parts and walks without human direction — marks an advance in inexpensive and versatile robotics that could ultimately be created for pennies, stacked like a deck of cards and deployed in spaces and applications where no robot has gone before.

The robot, created by researchers at Harvard and MIT who published their work in *Science* in August, is made of paper and 3-D sheets of polystyrene from the children's art toy Shrinky Dinks. Embedded wires heat and shrink the material in certain places, allowing the robot to fold like a piece of origami or unfurl like a flower petal.

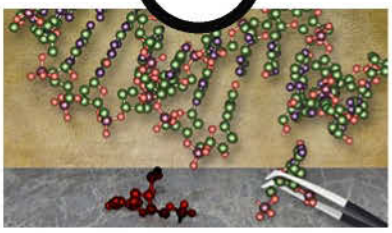
Researchers envision using such robots in places where humans can't easily go — a ream of sheets sent into space could unfold into a satellite, for example. They also could revolutionize manufacturing and allow people to design and print their own robot to do whatever they want, even play games with their cat, suggests Daniela Rus, director of the Computer Science and Artificial Intelligence Laboratory at MIT and one of the lead scientists on the project. "This would really democratize robots," she says.

—KAREN WEINTRAUB

See the robot in action at DiscoverMagazine.com/Robot

TOP: KAREN CARR. BOTTOM: SETH KROLL/WYSS INSTITUTE

38



A Giant Step for Gene Surgery

Just two years ago, Jennifer Doudna of the University of California, Berkeley, commandeered a process that bacteria use to fend off viruses, creating a molecular scalpel to snip out defective genes. The finding launched a genetic engineering gold rush, and since then, researchers have raced to use the new method, called CRISPR, to treat — and perhaps even cure — genetic diseases.

In March, Daniel Anderson's team at MIT moved out in front in that race by using CRISPR to repair a faulty gene in adult animals. The researchers corrected a mutation in liver cells in mice by snipping out the gene and sewing in a healthy copy of it. This cured the mice of the hereditary disease tyrosinemia, which causes the amino acid tyrosine to accumulate and can lead to liver failure.

The method repaired the gene in just one in 250 mouse liver cells, but those cells replicated enough to break down tyrosine and cure the disorder. Anderson and others are already exploring new gene-delivery methods, including nanoparticles, to better deliver gene-editing therapies to target tissues.

"If we want to treat the greatest number of diseases, we need to figure out how to get these molecules inside the cells of patients — not just increasing the number of target cells but also hitting tissues other than the liver," says Anderson, who co-founded a company called CRISPR Therapeutics to pursue those goals. The method could one day help treat human diseases, including Huntington's, hemophilia and sickle cell anemia.

"It's very exciting because it means we now have a technology that enables rewriting of the genome," Doudna says. —KARI LYDERSEN

CLOCKWISE FROM TOP: CHRISTINE DANILOFF/MIT; SIMON KATTENHOR AND LOUISE PROCKTER/NASA/JPL-CALTECH (2)

39

Europa's Icy Jigsaw Puzzle Solved

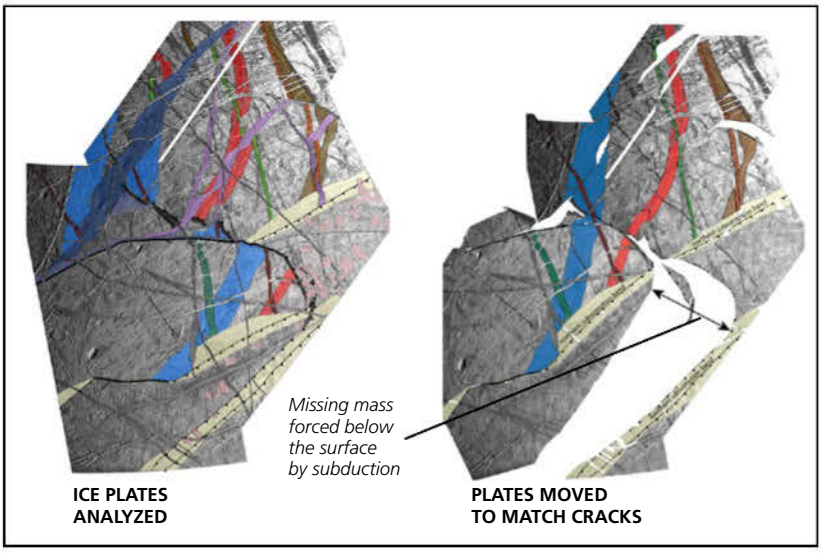
Ever since NASA's two Voyager spacecraft snapped the first photos of icy cracks crisscrossing Jupiter's moon Europa in 1979, astronomers have speculated that tectonic forces could be at work. But the first solid evidence didn't arrive until September, when a team of planetary geologists announced it might have solved the mystery by treating the moon's crust like a jigsaw puzzle.

Using data from the '90s-era Galileo probe, the team — led by Simon Kattenhorn, a structural geologist and planetary scientist at the University of Idaho — digitally deconstructed one region of the moon's surface into icy pieces, then tried to fit them back together. Researchers were surprised to find a 7,700-square-mile piece (about the size of Wales) missing, but they theorized that it had moved over warmer ice layers until it collided with another plate and was forced beneath the surface, out of view. (This process, called subduction, creates mountain ranges, volcanoes and trenches on Earth.) NASA officials say it's the first evidence that a body other than Earth has active plate tectonics.

The find isn't just geologically interesting: The movement of material from the inhospitable surface down into the ocean could supply crucial chemical nutrients for possible living organisms in the global ocean far below. —ERIC BETZ

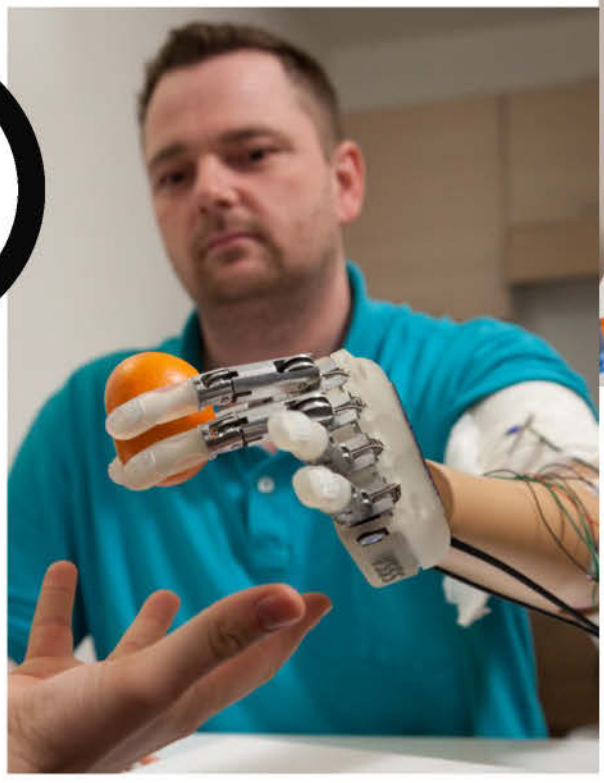


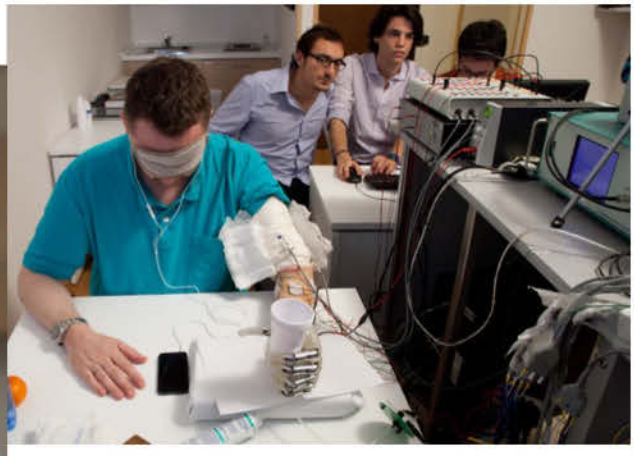
Jupiter's moon Europa, at right, has fascinated astronomers with its intricate and colorful cracks. Astronomers assembling the "puzzle pieces" of its icy surface discovered a large missing piece.

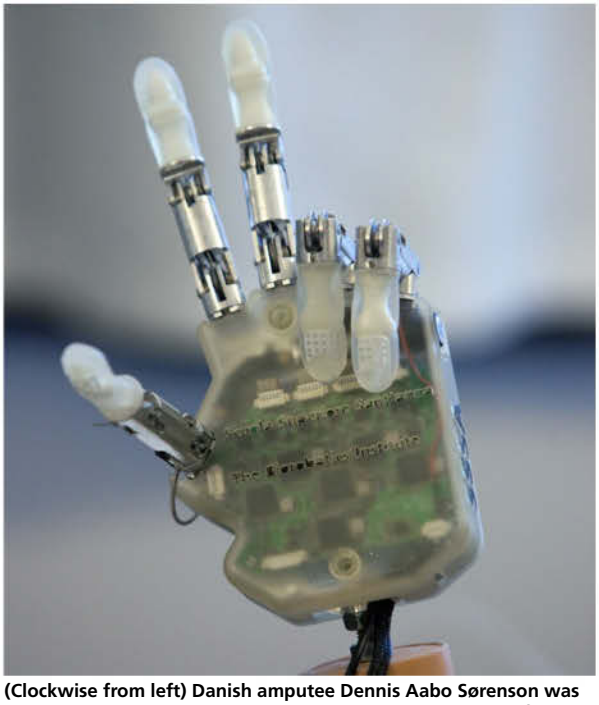


A Sensitive Advance in Prosthetics

40







(Clockwise from left) Danish amputee Dennis Aabo Sørenson was able to distinguish between similar objects and even identify a majority of objects in blind tests. The hand sends signals via sensors in the hand's "tendons" to nerves in the patient's arm.

The road to a major breakthrough in prosthetics began decades ago with a young Italian boy in front of a TV.

"I watched *The Six Million Dollar Man*, fascinated by the idea of connecting the natural and the artificial and using this technology to help people," says Silvestro Micera, now the lead researcher of the European LifeHand 2 project.

In February, Micera and his colleagues announced that they had successfully tested the first artificial hand to provide its user with real-time sensory feedback that can be used to modulate grasping force.

The bionic hand creates sensation by sending signals from sensors embedded in the artificial hand's "tendons" to electrodes implanted in the remaining nerves of the wearer's arm. The signals are precise enough that the wearer can distinguish between objects of similar shape but different stiffness, such as an orange and a baseball.

The team's next step will be to make the prosthetic more portable; it's currently connected to a control box. Micera notes other researchers are pursuing similar technologies, and he expects real-time sensory prosthetics to be available to amputees within a decade.

"This was simply the end of a story that started 20 years ago," says Micera. "In principle, we showed this could work. At the very end, whether I bring it to clinical practice or my competitors do, I know it will work." – GEMMA TARLACH

LIFEHAND 2/PATRIZIA TOCCI

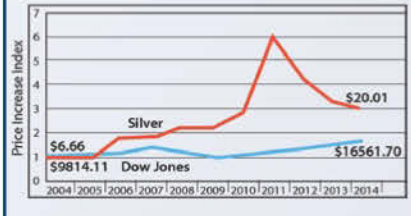
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41

Archaeologists Explore Largest-Ever Greek Tomb

Large stone sphinxes, women sculpted in marble, intricate mosaics and multicolored frescoes awaited archaeologists in August when they entered the largest tomb ever found in Greece.

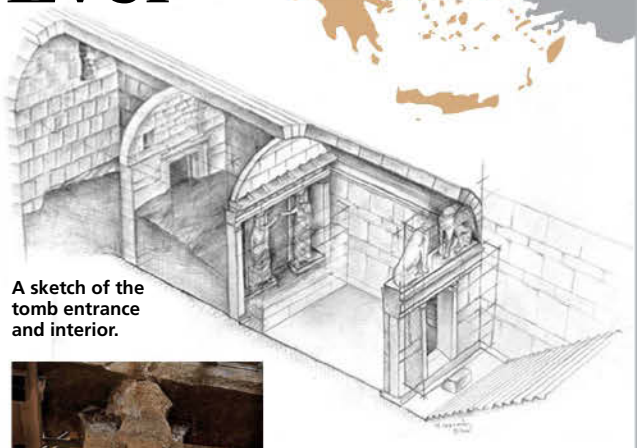
The scale of the tomb, which dates to the fourth century B.C., suggests it may belong to Roxane, wife of Alexander the Great, or their son, also called Alexander. Both were killed by political rivals after the death of the Macedonian conqueror in 323 B.C.

The burial complex, which doesn't appear to be looted, was found outside the ancient Macedonian city of Amphipolis in 2012, but its entrance wasn't located until August.

Throughout autumn, stunning new finds emerged almost daily, including a large floor mosaic depicting Pluto's abduction of Persephone.

The dig has not been without controversy. Greek Prime Minister Antonis Samaras pre-empted the archaeologists in announcing the discovery. Groups such as the Association of Greek Archaeologists have complained that the subsequent relentless media coverage, floods of tourists and increased risk of looting are compromising ongoing work at the site. – GEMMA TARLACH





A sketch of the tomb entrance and interior.





One of two caryatids (left), sculpted female columns, guards the second chamber. A mosaic (above) on the floor of that chamber depicts Pluto's abduction of Persephone. Two sphinxes (below) stand above the tomb's entrance. One of the heads was found in October.





A 500-meter-long, 3-meter-tall limestone and marble wall circles the massive tomb, seen above in a satellite view.



See more photos of the tomb, including details of the artifacts within, at **DiscoverMagazine.com/Tomb**

CLOCKWISE FROM TOP: ROEN KELLY/DISCOVER; HCM/POLARIS (4); ALEXANDROS MICHAILIDIS/AP PHOTO/CORBIS; GOOGLE EARTH

42



Fields Medal recipient Maryam Mirzakhani sketches out a geometry problem.

Fields Day

At 37, Maryam Mirzakhani has become the first woman to be awarded the Fields Medal, often considered the highest honor in mathematics. Born in Tehran, Iran, Mirzakhani came to the U.S. to attend graduate school at Harvard. There, she began to research hyperbolic surfaces, geometric objects that can be visualized as having a saddle shape at every point. Later, she made an enormous breakthrough in understanding the trajectories that balls would trace if they bounced forever around a billiard table of nearly any shape. "This is amazing, formidable work," says Etienne Ghys, a member of the Fields Medal committee. "Sometimes mathematics is easy and fun and a pleasure, and sometimes you have to suffer for it. This took suffering." — JULIE REHMEYER



The Fields Medal is awarded every four years by the International Congress of Mathematicians.

FROM LEFT: THOMAS LIN/QUANTA MAGAZINE; STEFAN ZACHOW/INTERNATIONAL MATHEMATICAL UNION; JAY SMITH, AFTER SYNTHORX

43

First Organism With Artificial DNA Debuts

A chimera, in Greek mythology, is a creature made from parts of different animals — an alien monster. That's how some might view the organism created by a team at Scripps Research Institute in California.

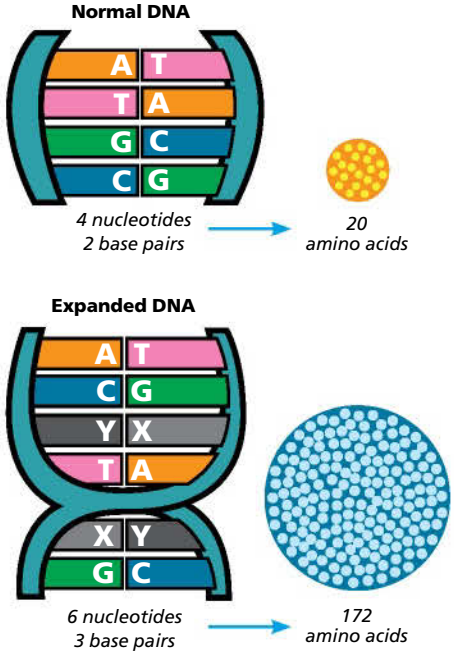
Expanding upon DNA's complement of four chemical nucleotides, or "letters" (A, T, C and G), the scientists concocted a totally unnatural pair of nucleotides, dubbed X and Y. As reported in *Nature* in May, the team inserted the two into a bacterial cell, a strain of *E. coli*. When the cell reproduced, unwinding its double helix and reconstituting it in new cells, X and Y replicated as well, their chemical bond just as stable as the A-T and C-G pairings in DNA's normal sequence.

The leader of the Scripps team, Floyd Romesberg, calls the organism "semi-synthetic." He promises it could never survive outside the lab because the foreign nucleotides, deprived of their chemical feedstock, would quickly be deleted. "We are focused on what's practical," he says. "We're not trying to create new life, but to increase proteins' potential. … With more [DNA] letters, you can tell more interesting stories."

DNA encodes amino acids, which are the building blocks of proteins. These proteins, in turn, are the building blocks of life. DNA's four nucleotides have enabled 20 amino acids. By adding just one more pair of letters, chemists could potentially have 172 amino acids to work with, and a limitless number of new proteins.

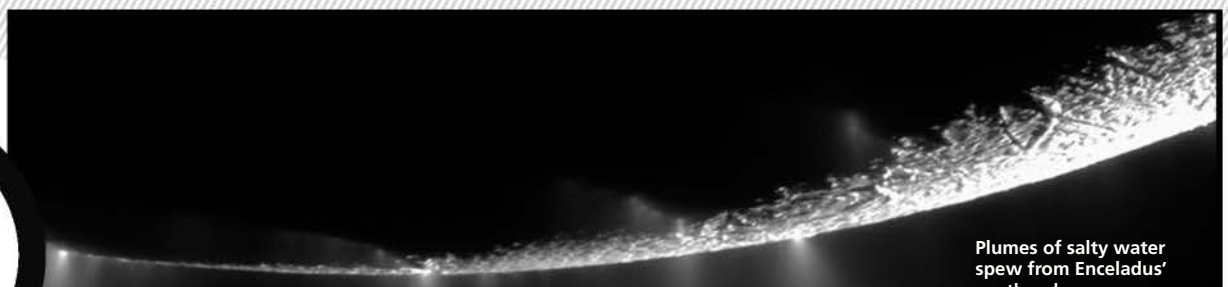
Pharmaceutical companies increasingly look to proteins as templates for new drugs. However, protein molecules are much larger than most drug molecules, and synthesizing them is a "laborious, one-at-a-time" process, says Romesberg. "It's a huge advantage that the cell does the heavy lifting for you."

Cell factories, their DNA tweaked by different combinations of nucleotides, may one day generate therapeutic proteins that could be tested against each other in cultures. Romesberg calls this "directed evolution — you apply selection pressure to the cells, and you [keep] those that do what you want the best." — JEFF WHEELWRIGHT



Normal DNA is made up of the nucleotides adenine, thymine, cytosine and guanine. Adding just one more pair of "letters" — X and Y — to the genetic alphabet opens the door to 172 amino acids, which could be used to build new proteins.

44



Plumes of salty water spew from Enceladus' south pole.

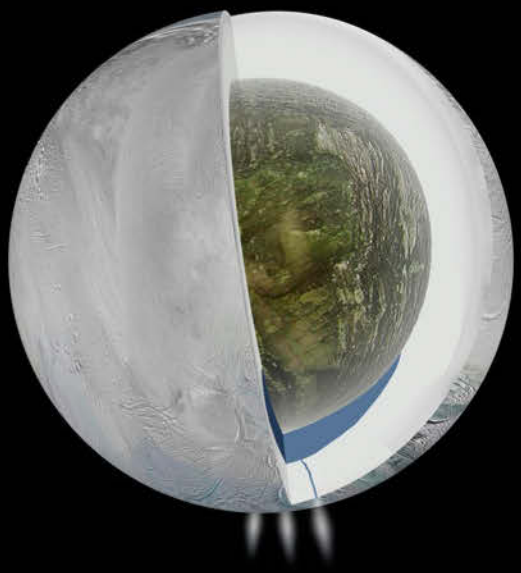
Saturn's Moon Hides Liquid Water

In the search for life, astronomers follow the water. Ten years ago, the search led them to Saturn's moon Enceladus, where they discovered several plumes on the south pole spewing water into space. In 2014, scientists finally found their source: a huge lake about 20 miles under the surface ice.

Luciano Iess of the University of Rome La Sapienza and his colleagues suspected such an underground reservoir might exist, so they used NASA's Cassini probe to investigate. The spacecraft measured Enceladus' gravitational tug at various points during three passes just 30 to 60 miles from the surface. The stronger gravity's pull, the more mass lay directly below.

When Iess and his team spotted an unusually massive area near the south pole with no corresponding topography (a mountain, say), they realized that a denser material — liquid water — lurked below. The results showed this frozen world hardly the size of the Gulf of Mexico holds a 5-mile-deep reservoir about the size of Lake Superior.

A few months later, other Cassini researchers identified 101 distinct geysers on the moon. Those spouts offer many pathways for the water — and any other ingredients for life — to burst up through the surface. — LIZ KRUESI



A large lake likely lies between the outer icy shell of Enceladus and its rocky core.

45

Blood Test Could Predict Suicide Risk

Suicide ravages freely, claiming old and young, rich and poor, famous and unknown. But some people face increased risk, and current tests don't spot them early enough to intervene effectively.

In July, molecular biologist Zachary Kaminsky of Johns Hopkins University and his team reported a simple way to detect people with suicidal tendencies — with a blood test. They examined DNA from brain tissue of people who died by suicide and those who died of other causes and measured its methylation — levels of chemicals called methyl groups on DNA that alter gene expression. They found that a stress-mitigating gene called SKA2 was less active in those who died by suicide and was more likely to be methylated. Experts believe that when SKA2 is too sluggish, some people can't stop their negative thoughts and fears.

Kaminsky's team then developed a blood test that measured SKA2 activity and levels of methyl groups, then fed its results, plus data on demographics and stress level, into a statistical model. In a small test, that model predicted suicidal thoughts or suicide attempts with a remarkable 80 percent accuracy.

The team still needs to run larger trials before this test will be ready for doctors' offices, but Kaminsky has high hopes for its potential. It's "another way to ask for help," he says. — BRENDA POPPY

FROM TOP: NASA/JPL/SPACE SCIENCE INSTITUTE; NASA/JPL-CALTECH

Mammography Wars Reignite

46

For more than two decades, the power of mammograms to save lives has remained a point of controversy. The debate reignited in February with a study published in the journal *BMJ* showing that screening mammography failed to reduce breast cancer deaths.

The study enrolled nearly 90,000 Canadian women, age 40 to 59, and followed them for 25 years. Although women who got mammograms had more breast cancers detected than those who didn't, this increase in detection did not translate into lives saved. Researchers used statistical analysis to calculate that 22 percent of the invasive cancers found would never show symptoms. Women received unnecessary treatment for cancers that did not threaten their lives. "There are all harms and no benefits," says study author Anthony Miller, a physician and epidemiologist at the University of Toronto.



A. BENOIST/BSIP/CORBIS

A study that followed Canadian women over 25 years found that more mammograms and cancer detection did not result in more lives saved.

The emphasis on harms represents a new shift in the public discourse about mammography's value. Since it began in the early 1990s, the debate over mammography has centered on how many lives the test could save. But recently, the conversation has widened to include the growing recognition that screening mammography may also needlessly transform healthy people into cancer patients.

Mammography proponents, such as the American College of Radiology, contend that the study is fatally flawed because outdated mammography machines didn't find as many breast cancers as more advanced machines would.

But the traditional "look harder/find smaller" approach assumes that cancer is a universally progressive disease that always metastasizes and kills unless it's stopped in an early stage. Research now shows that not every cancer progresses this way, says H. Gilbert Welch, a professor of medicine at Dartmouth College and author of the book *Should I Be Tested for Cancer?: Maybe Not and Here's Why*. Some cancers metastasize before they're discernible, while others grow so slowly that they won't turn invasive in the person's lifetime.

It's now clear that mammography is very good at finding slow-growing, harmless cancers, says Welch. What remains contentious is the extent to which it also finds early cancers that could become deadly yet still respond to treatment.

The *BMJ* study is one of several trials that have quantified the benefits of screening mammography. These studies estimate mammography decreases the number of deaths by anywhere from 35 percent to 0 percent, says Otis Brawley, chief medical officer at the American Cancer Society. Despite that wide range, he says the takeaway is similar: Mammograms cannot prevent every breast cancer death. If mammograms reduce deaths by a third (as the rosiest estimates suggest), Brawley says, that still means regular high-quality mammograms won't save the lives of about two-thirds of women with deadly breast cancers.

The Canadian study is especially important because newer, more effective treatments for breast cancer were available during the 25 years when study participants were followed. A 2010 study published in the *New England Journal of Medicine* calculated that about two-thirds of the recent reductions in breast cancer mortality did not come from screening but from other causes, such as better treatments.

The February study in *BMJ* was published with an editorial arguing that it's time for policymakers to reassess mammography recommendations. The U.S. Preventive Services Task Force was already doing so when the study results came out, says Michael LeFevre, chairman of the task force and a physician at the University of Missouri. He predicts the task force's draft of updated recommendations will be published in late 2015. Until then, he's following the 2009 guidelines, which call for individualized decision-making for women in their 40s and biennial screening for women 50 to 74. – CHRISTIE ASCHWANDEN

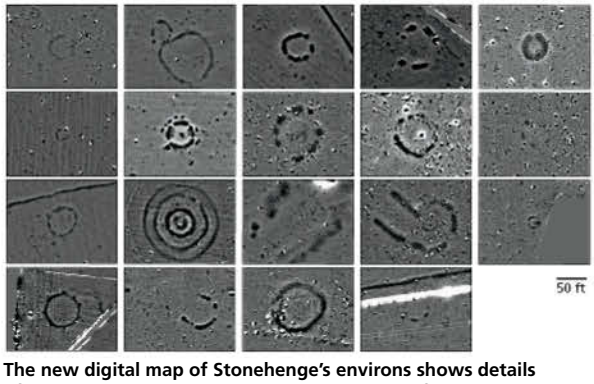
47



The iconic Stonehenge monument has captivated humans for five millennia, but a new digital map of its surroundings reveals the stones are just one small part of a massive network of Neolithic sites.

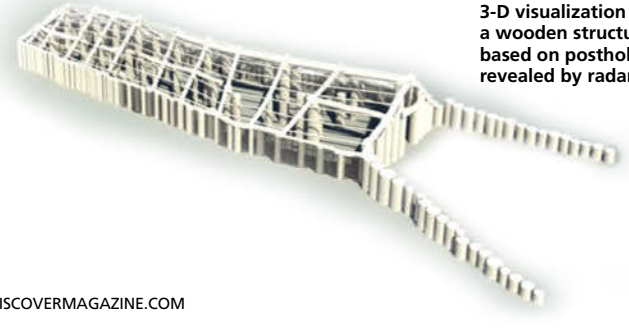
Stonehenge's Buried Secrets Uncovered

Stonehenge is the 5,000-year-old gift that keeps on giving. Using ground-penetrating radar and 3-D laser-mapping techniques, British scientists identified 17 additional Neolithic shrines hidden beneath a 4.5-square-mile swath of land surrounding the iconic site, 90 miles west of London. The new geophysical survey, released in September, includes several previously unidentified burial mounds and an earth and timber chamber, called a long barrow, that was likely used for excarnation: the act of removing flesh from the bones of the deceased in preparation for burial. —CARL ENGELKING



The new digital map of Stonehenge's environs shows details of numerous still-buried sites that had never before been identified, including pits, burial mounds and additional stone circles (above). Researchers used a motorized ground-penetrating radar array (below) to find the hidden archaeological treasures.



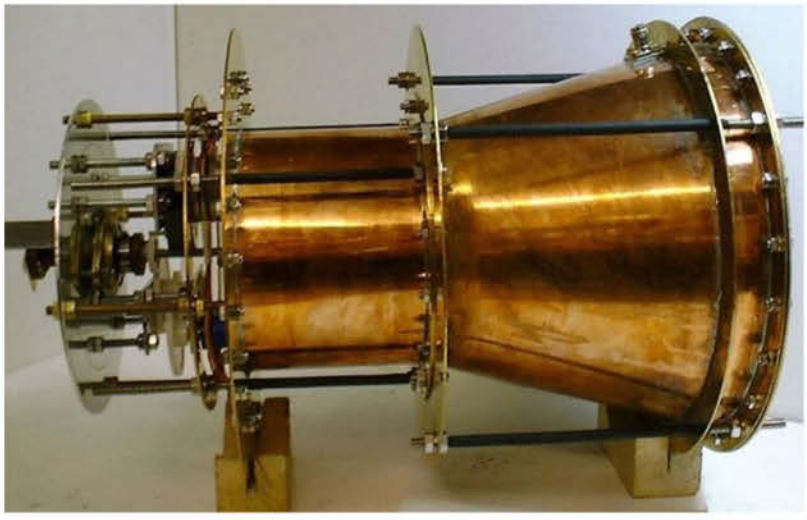


The team created a 3-D visualization of a wooden structure based on postholes revealed by radar.

CLOCKWISE FROM TOP: LBI ARCHPRO/GEERT VERHOEVEN; LBI ARCHPRO/MARIO WALLNER; VERHOEVEN; LBI ARCHPRO/JOACHIM BRANDTNER

This Space Drive Might Defy Physics

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The Cannae Drive could revolutionize space travel and our understanding of physics itself — if it really works. So far, physicists remain skeptical.

In 2014, five engineers at NASA's Jet Propulsion Laboratory tested independent inventor Guido Fetta's Cannae Drive, a prototype space engine that's basically a microwave emitter within a small metal cone. In July, they reported their incredible conclusion: The device moved, despite lacking propellant or producing exhaust of any kind.

It was a doubly bold claim, one that seemed to contradict conservation of momentum (a foundational principle of physics) and to promise a new era of fast, cheap space travel. The Internet was abuzz with excitement.

The physics community was less enthused. "Nonsense," physicist Sean Carroll at Caltech bluntly put it. "They claim to measure an incredibly tiny effect that could very easily just be noise." In their paper, the NASA researchers did not provide a full accounting of possible sources of error, but they did include a speculative outline for a Cannae Drive-powered trip to Mars.

More testing is necessary to show whether the Cannae Drive really has any potential; history is full of examples, from antigravity effects to cold fusion, of researchers fooling themselves when they know the desired outcome.

The Cannae Drive also calls attention to a growing crisis in space travel. NASA's upcoming deep-space rocket, the Space Launch System, uses the same engine design as the space shuttle launcher of the 1980s. If they hope to boldly go where nobody has gone before, scientists need to explore radical ideas in propulsion. Next time, though, they might want to test twice before they announce results. — COREY S. POWELL

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A New Angle on Light Control





The small block appears transparent to light approaching at 55 degrees from vertical, but reflects all other angles.

Humans know how to filter light: Stained glass only allows through light of a certain color, and polarized sunglasses block certain light waves. But filtering light based on the direction it's traveling has eluded scientists for decades.

But now, scientists at MIT devised a tiny block that can do just that. It's smaller than a stick of gum and made of 84 thin, alternating layers of glass and tantalum oxide (a compound often found in electronics). Viewed from most angles, the block reflects light like a mirror. At exactly 55 degrees from vertical (35 degrees from the block itself), however, it appears transparent, totally clear. That's because each of the 83 interfaces between the two materials filters some of the incoming light; only the light traveling at the correct angle makes it through the block (rendering it transparent). The rest bounces back as a reflection.

The March discovery could make computer screens more secure and help astronomers better filter light from stars and planets. Yichen Shen, a Ph.D. student who worked on the project, calls it "an essential step in achieving control over light." — SHANNON PALUS

TOP: SATELLITE PROPULSION RESEARCH LTD. BOTTOM: WEISHUN XU AND YUHAO ZHANG/MIT (2)

50



A prototype of Google's new self-driving car has built-in sensors designed to "read" city streets.

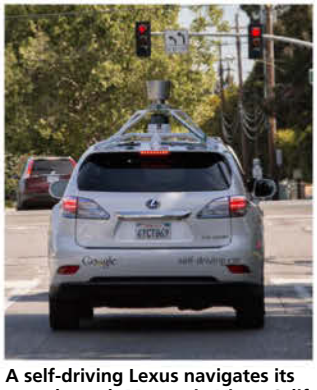
Google Car Moves Into Fast Lane

John Leonard watched spellbound from the back seat as the Lexus he was riding in drove through downtown Mountain View, Calif., one July day. The steering wheel spun right and left without a driver touching it. The car stopped at lights, switched lanes and even punched its accelerator as it merged into traffic.

For Leonard, a roboticist at MIT, riding in a car outfitted with Google's self-driving technology reminded him of another iconic moment in transportation: when the Wright brothers ushered in the age of air travel 111 years ago. "Honestly," he says, "I felt like I was on the beach at Kitty Hawk."

In 2014, it became more credible than ever that all cars will drive themselves someday. Google began building 100 more prototypes over the summer — this time, without steering wheels — and several mainstream car manufacturers, including BMW and Audi, demonstrated their own self-driving prototypes.

A Google car senses its surroundings through radar, cameras and range-finding lasers spinning atop the vehicle to create a 360-degree view of pedestrians, vehicles and intersections.



A self-driving Lexus navigates its way through Mountain View, Calif.

But Google's real trick is the map stored in the car's computer. The sensor-loaded cars are driven manually to scan roads in advance, revealing potholes, stop signs and other features that are then processed into a detailed map and downloaded to the autonomous car. This pre-mapping vastly simplifies the computing that a Google car has to do in real time, potentially reducing its price tag.

The challenge will be to create these centimeter-scale maps for thousands of roads worldwide and constantly update them as they change, says Alberto Broggi, an engineer developing self-driving cars at the University of Parma in Italy. "If you have wrong data, it would kill you," Broggi says. Autonomous cars will also need to read gestures and other cues from cyclists, pedestrians and traffic cops.

The mapping challenge, in particular, could take 30 years to address, says Leonard, though he admits, "Sometimes you need younger people who don't know how hard something is." — DOUGLAS FOX

Ride along in a test drive of the car at **DiscoverMagazine.com/Self-driving**

BOTH IMAGES: GOOGLE

Arctic Answer to Long-Lost British Ships

After nearly two centuries, a team of underwater archaeologists cracked one of the greatest maritime mysteries in Canadian history. In September, the team announced the discovery of a British vessel — identified in October as the HMS *Erebus* — that was one of a pair to disappear while attempting to chart the Canadian Arctic's Northwest Passage in 1845.

Experts believe ice trapped the *Erebus* and the HMS *Terror* in 1846, dooming the 128 crewmen and their leader, explorer Sir John Franklin. Parks Canada researchers finally located the vessel with a remotely operated underwater vehicle.

Although the *Terror* has yet to be found, the well-preserved *Erebus* wreckage could provide clues to its location, as well as offer insight into the crews' last days. – BRENDA POPPY



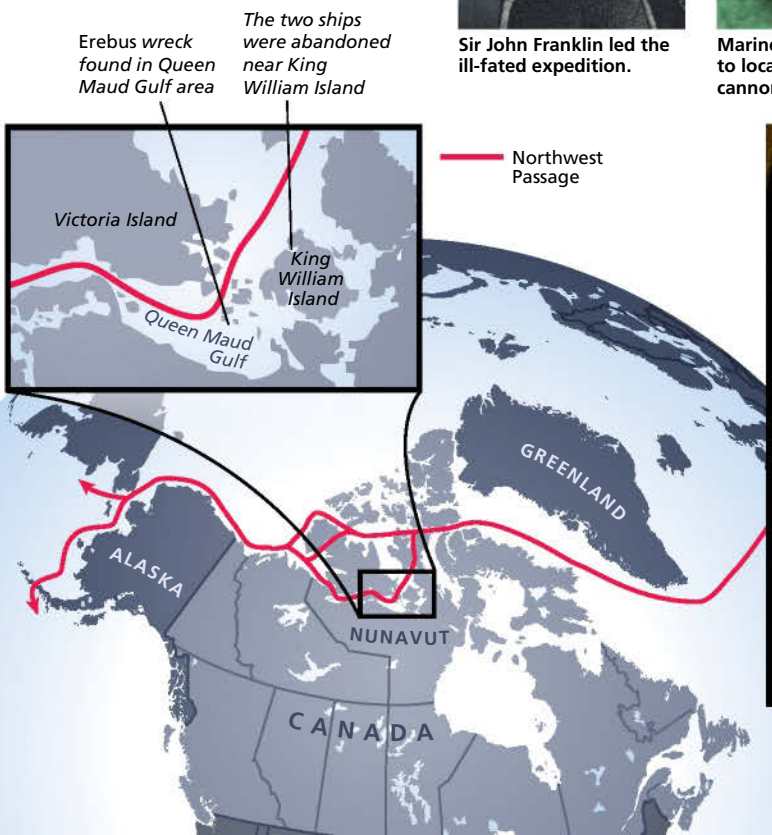
This painting, from H.E. Marshall's 1905 book *Our Island Story*, depicts some of the more than 100 crew members who abandoned the HMS *Erebus* and HMS *Terror* after nearly two years of being trapped in ice in the Canadian Arctic. No one survived.



Sir John Franklin led the ill-fated expedition.



Marine archaeologists used a remotely operated vehicle to locate *Erebus*' wreckage, which included these two cannons scattered amid the ship's timbers.

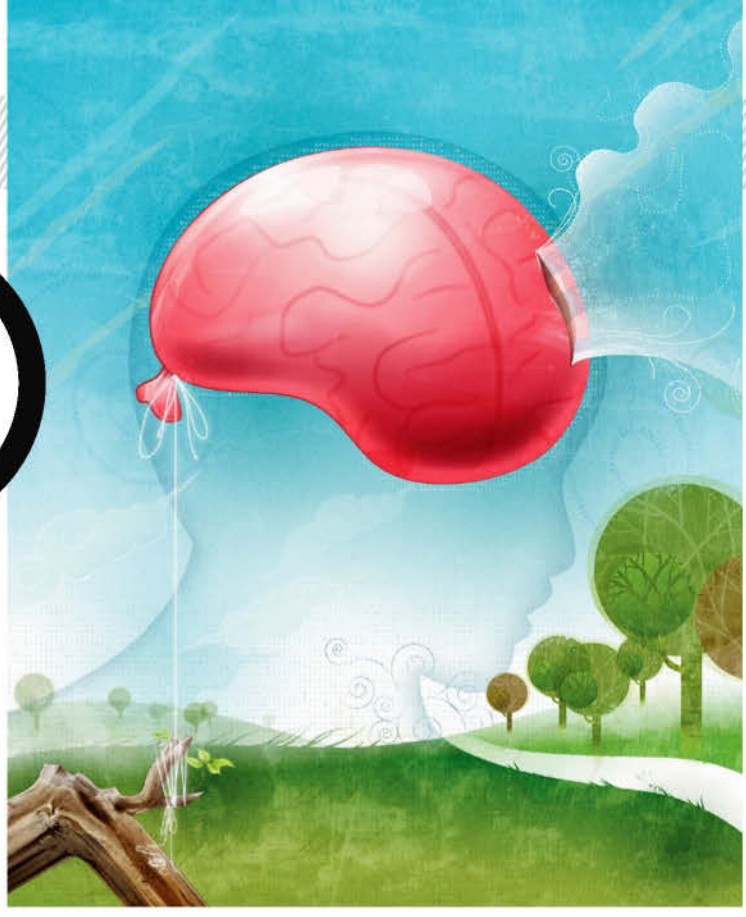




The team used sonar technology to capture this underwater image of what they later identified as the wreckage of the long-lost *Erebus*.

COUNTERCLOCKWISE FROM BOTTOM RIGHT: PARKS CANADA (2); PRINT COLLECTOR/GETTY IMAGES; WELLCOME LIBRARY, LONDON; ROEN KELLY/DISCOVER

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How Was My Childhood? I Forget.

What's your earliest memory? Most people can't remember events before about age 3, a phenomenon called infantile amnesia. In May, researchers announced they finally might have pinpointed the cause.

As neurons form rapidly during infancy and early childhood — through a process called neurogenesis — new neurons rearrange connections and destabilize existing memories. Mice, like humans, display infantile amnesia. To explore why, researchers trained mice to fear a particular environment, then gave some mice access to running wheels, since exercise is known to stimulate neurogenesis. Afterward, researchers found, the exercisers had largely forgotten their fear, whereas the sedentary mice still remembered it.

The researchers then examined the opposite effect: slowing neurogenesis in infant mice by giving them a drug. They found that mice whose neuron growth was stunted were much more likely to remember their earlier fear a week later.

All this hints that a similar mechanism may be at work in humans' early childhood.

The group plans to study the utility of forgetfulness next. Normally people think forgetting something is bad, but certain types of forgetting can be helpful, study author Paul Frankland says: "It works better to forget lots of details. You don't want your mind cluttered up with that stuff."

So don't fret your forgotten youth. You may have it to thank for lots of memories gained since then. — LISA RAFFENSPERGER

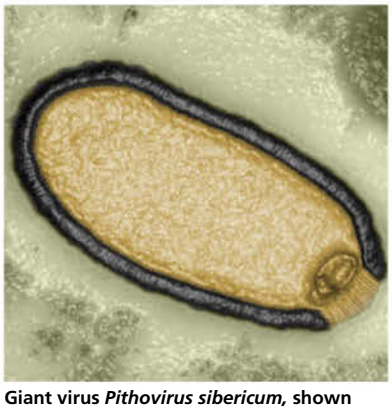
53

Waking a Sleeping Giant (Virus)

Locked deep in 30,000-year-old Siberian permafrost, a sleeping giant lay in wait — a giant virus, that is. *Pithovirus sibericum*, a newly discovered giant virus, was still viable when virologists Jean-Michel Claverie and Chantal Abergel thawed the permafrost around it.

Waking *P. sibericum* marks the first time researchers sidestepped complicated lab techniques typically used to revive dormant viruses. Instead, the team announced in March, they simply warmed the frozen soil and added amoebas, common hosts for giant viruses. Once they observed *P. sibericum* replicating in its new host, they knew the ancient virus was still viable.

The virus is also physically bigger than members of the *Pandoravirus* genus, formerly the largest, by about 30 percent. (Yet Pandoraviruses still have bigger genomes than *P. sibericum* — about 2.5 million base pairs versus *P. sibericum*'s 600,000 base pairs.) Its resilience raises concern over what other unknown viruses humans might encounter as large-scale mining and drilling projects, not to mention increasingly warm temperatures, thaw more permafrost. — LACY SCHLEY



Giant virus *Pithovirus sibericum,* shown here in an electron microscope image, is large enough to be seen even under an optical microscope. It was named for the Greek word *pithos*, the type of container famously given to Pandora by the gods.

LEFT: HUAN TRAN/IKON IMAGES/CORBIS. RIGHT: JULIA BARTOLI AND CHANTAL ABERGEL/INFORMATION GÉNOMIQUE ET STRUCTURALE, CNRS-AMU

E-Cigarette Use Draws Health, Regulatory Attention

54

Their popularity soaring, electronic cigarettes came under intense scrutiny by health researchers and regulators in 2014, even as the world's biggest tobacco companies made moves to profit off them.

E-cigarettes deliver nicotine by vaporizing a nicotine-loaded liquid rather than burning tobacco. Sales of the product had already jumped from a mere 50,000 sold in 2008 to 3.5 million in 2012. By 2014, a British study found that just over half of smokers there had used e-cigarettes.

But despite the claim that e-cigarettes offer a healthier alternative to smoking, the Centers for Disease Control and Prevention reported in April that the number of calls to poison centers involving e-cigarettes jumped from a single call per month in September 2010 to 215 calls per month in February 2014. Nearly 6 in 10 of those calls involved people younger than 20, and 51 percent of the total calls involved kids younger than 5.

Even when properly used by adults, e-cigarettes have been shown to have immediate adverse effects on respiratory function. They produce more ultrafine particles than cigarettes do, and they cause the same reduction in the amount of nitric oxide exhaled by users — a consequence long associated with smoking's harmful cardiovascular effects.



Liquid nicotine in e-cigarettes is vaporized and inhaled. The devices have been shown to produce more ultrafine particles than cigarettes.

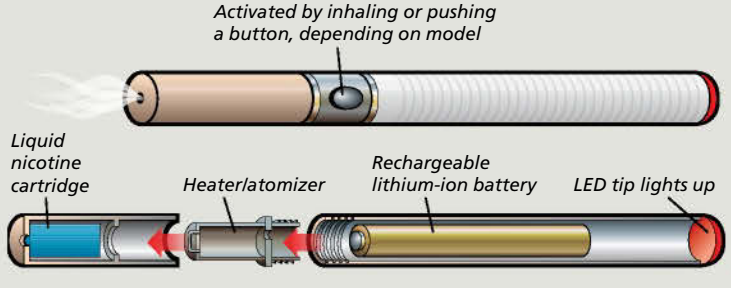
Not all the health news was bad: A survey of smokers who tried to quit found they were 63 percent more likely to succeed if they switched to e-cigarettes than if they used either nicotine gum or patches, or relied on willpower alone. In all, 20 percent of the smokers reported that they had stopped smoking conventional cigarettes if they used e-cigarettes, compared with 10.1 percent using over-the-counter nicotine replacement aids and just 15.4 percent who went cold turkey.

Still, the overall picture looks bleak to researchers like Stanton Glantz, director of the Center for Tobacco Control Research and Education at the University of California, San Francisco. "We're on a very bad trajectory," he says. "They're being marketed extremely aggressively in ways that are rapidly penetrating the youth market."

But just as the world's two largest tobacco manufacturers, Reynolds American (maker of Camel) and Altria (maker of Marlboro) were entering the market, the FDA announced its intention in April to regulate e-cigarettes as it does traditional cigarettes — including age restrictions and health warnings. – DAN HURLEY

HOW IT WORKS: ELECTRONIC CIGARETTES

A battery activates a heating device inside the e-cigarette, vaporizing the liquid inside the nicotine cartridge to create a "smoke" the user can inhale.



TOP: SEBASTIEN NOGIER/EPA/CORBIS. BOTTOM: JAY SMITH

55

Futuristic Contact Lens in Sight

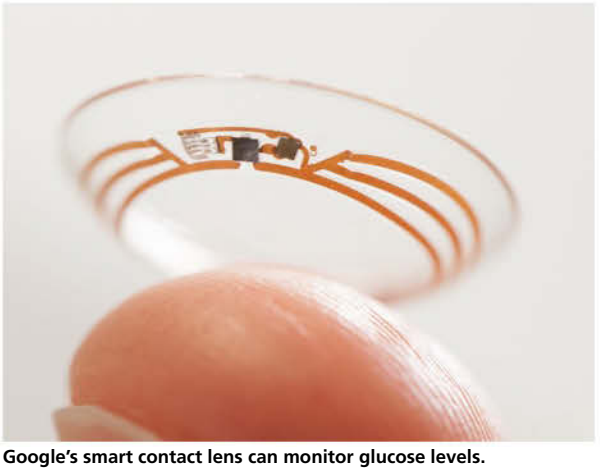
Smart technology makes tracking personal health metrics — from posture to sleep quality — easier than ever. But one new device could be more medically useful than any yet on the market: a smart contact lens.

Developed by Google's secretive Google X arm, the initial prototype is designed to monitor glucose for diabetics. It sports a tiny sensor that measures glucose in tears and an antenna that wirelessly transmits the data to a connected device.

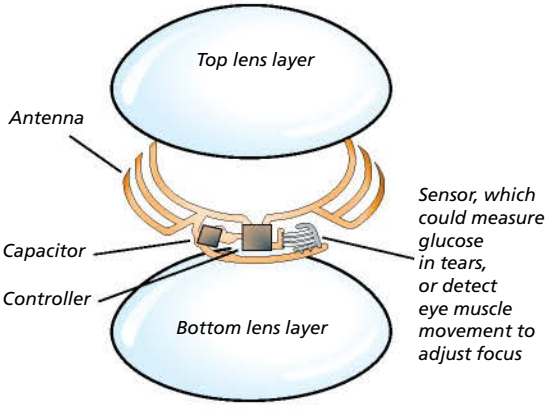
Google's clinical research studies demonstrate the device can take one reading per second, promising a constant, noninvasive alternative to diabetics' routine finger pricks throughout the day. The lens could also immediately alert patients, doctors or caregivers to abnormal glucose levels.

A different twist on the same technology could produce lenses that work better than current bifocal contact lenses. By detecting eye muscle movements and automatically adjusting focus — similar to an automatic camera lens — the new lens could replicate the eye's natural functioning.

In July, pharmaceutical giant Novartis announced it would license and commercialize the lenses, initially focusing on these two applications. CEO Joseph Jimenez said the company wants a prototype available for research-and-development reviews by early 2015, though Novartis says it's too early to say which version of the lens will be available first. — LISA RAFFENSPERGER

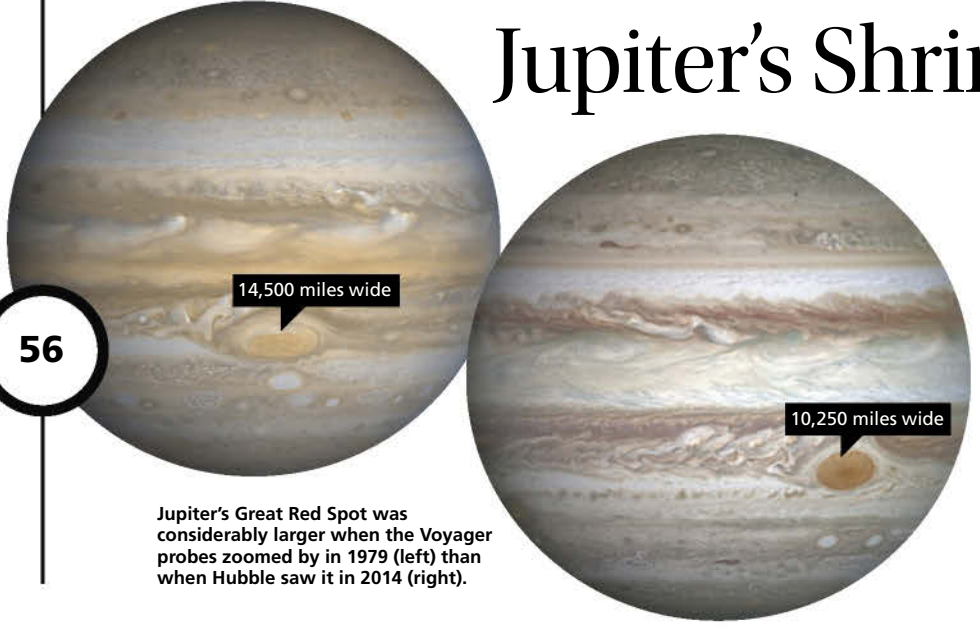


Google's smart contact lens can monitor glucose levels.



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Jupiter's Shrinking Spot



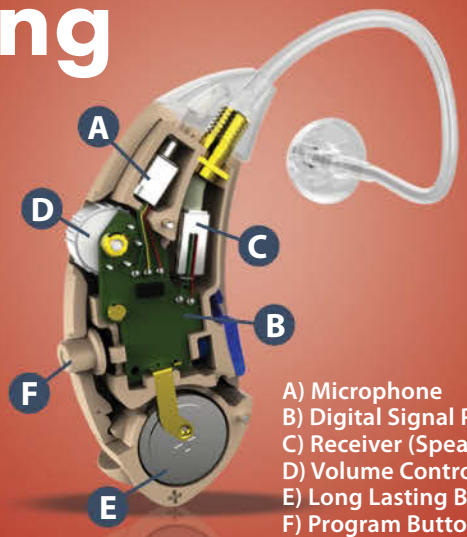
Jupiter's Great Red Spot was considerably larger when the Voyager probes zoomed by in 1979 (left) than when Hubble saw it in 2014 (right).

Astronomers have known for decades that Jupiter's trademark weather pattern — the stormy Great Red Spot — is shrinking. But in May, after taking a closer look with the Hubble Space Telescope, they learned that lately the spot has been shrinking at a faster rate. In 1979, when Voyager 1 and Voyager 2 flew by, the Great Red Spot was 14,500 miles wide. Now it's just 10,250 miles wide and shrinking by 580 miles per year. The cause of the big shrink remains a mystery. — LIZ KRUESI

FROM TOP: GOOGLE; JAY SMITH AFTER GOOGLE PATENT; 1979 JUPITER, NASA/JPL/BJORN BJORN JONSSON; 2014 JUPITER, NASA, ESA AND AMY SIMON (GODDARD SPACE FLIGHT CENTER)

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FDA Approves First Powered Exoskeleton

A powered exoskeleton, long an object of fascination for science fiction writers and researchers alike, won federal approval last summer. Now paraplegics can use the device to sit, stand and walk.

The ReWalk first made headlines in 2012 when the device, then experimental, helped a woman with paraplegia complete the London Marathon. On June 26, the FDA gave the go-ahead to market it directly to consumers, and two weeks later, a retired U.S. Army sergeant became the first patient in the U.S. to take one home. A Veterans Affairs official said the agency would pay the $69,500 price tag, but it's unclear whether private insurers or Medicare will cover the device.

The ReWalk includes a metal brace supporting the legs and upper body; motors at the hips, knees and ankles; and a backpack containing a computer and battery. Buttons on the wrist command the device to sit down, stand up or walk. When activated for walking, a sensor detects when the wearer leans forward and then initiates a step.

The paralyzed creator of ReWalk, mechanical engineer Amit Goffer, will not benefit from his invention, however. He's a quadriplegic, so he cannot control it. But, he says, "this is only the beginning." His company is developing similar systems for quadriplegics and those with neurodegenerative illnesses.

—DAN HURLEY



Retired U.S. Army Sgt. Theresa Hannigan demonstrates the ReWalk for Pennsylvania congressman Chaka Fattah in May.



Wrist device commands the exoskeleton to sit, stand or walk



The ReWalk exoskeleton

Watch a video of the ReWalk exoskeleton in action at **DiscoverMagazine.com/Walk**

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Laser Technique Reverses Tooth Decay

The drill-and-fill approach to fixing cavities may eventually have new competition, thanks to Harvard University biomedical engineer David Mooney and National Institutes of Health assistant clinical investigator Praveen Arany. The pair, along with colleagues, reported in May that they had developed a new technique that stimulates the growth of dentin, the hardened tissue below tooth enamel, through the use of a simple, low-powered laser.

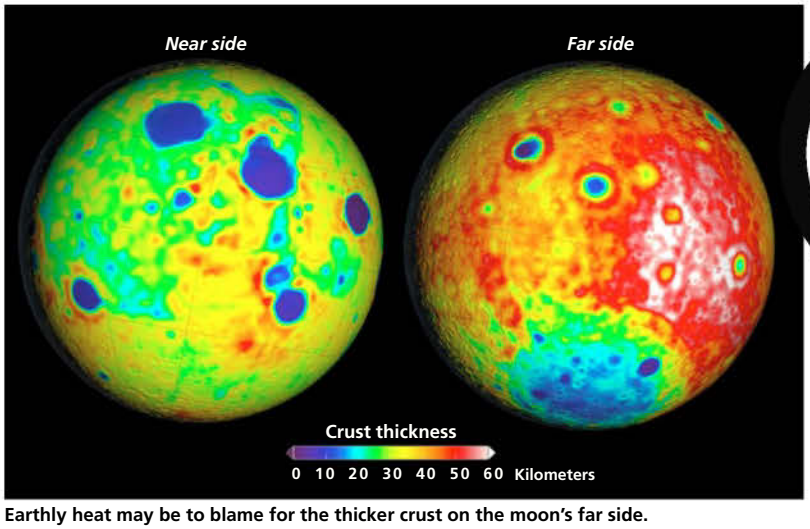
Arany drilled holes in the teeth of rats, shined a light similar to a laser pointer into the false cavities for five minutes, then capped them. Twelve weeks later, the dentin inside had grown back. By studying the same process in cultured cells, the scientists found that the light stimulated a molecular chain reaction that activated a normally dormant protein called TGF-beta 1. That protein, in turn, prompted nearby dental stem cells to differentiate into dentin-forming cells, which then differentiate into mature dentin. The protein also activates other kinds of stem cells, which means the method could be used to regenerate other tissues.

The technique could combat tooth sensitivity and cavities. "It's not going to replace the root canal," Arany says, but you might be able to prevent one in the first place with dentin regeneration.

—GREGORY MONE

FROM LEFT: PRNEWSFOTO/OFFICE OF CONGRESSMAN FATTAH; REWALK ROBOTICS (2)

Beneath the Moon's Two Faces



Earthly heat may be to blame for the thicker crust on the moon's far side.

Astronomers have finally figured out why the moon is so two-faced, and it turns out the answer was with us all along: It's Earth's fault.

The moon's two faces look nothing alike. The far side has significantly fewer of the familiar dark patches, formed by ancient lava flows. That's because the lunar crust is thicker there, making it harder for asteroid impacts to break through and release magma. But why was the crust thicker to begin with?

A team of Pennsylvania State University astronomers came up with a likely answer last summer, one that dates back to the moon's formation. When a Mars-size body collided with the young Earth some 4.5 billion years ago, the material that shot into orbit eventually coalesced and cooled into the solid moon, with one side always facing Earth. But the crash also heated our planet to over 7,000 degrees Celsius (13,000 degrees Fahrenheit), energy that irradiated the moon's near side, keeping it molten much longer.

The far side, on the other hand, cooled sooner, making conditions more favorable for material to condense there. That material became lunar rock, resulting in a thicker crust on that hemisphere.

A similar process can probably occur on extrasolar planets that are heated to lopsidedness by their host stars, so at least the moon isn't the only one with two faces. —KATHERINE KORNEI

2014 World Debut: New Species Series



Call for Help

2014 World Debut: New Species Series

Boophis ankarafensis

Type of animal: Tree frog

Description: Bright green; reddish-brown speckles on head and back

Home: Ankarafa Forest in northwest Madagascar



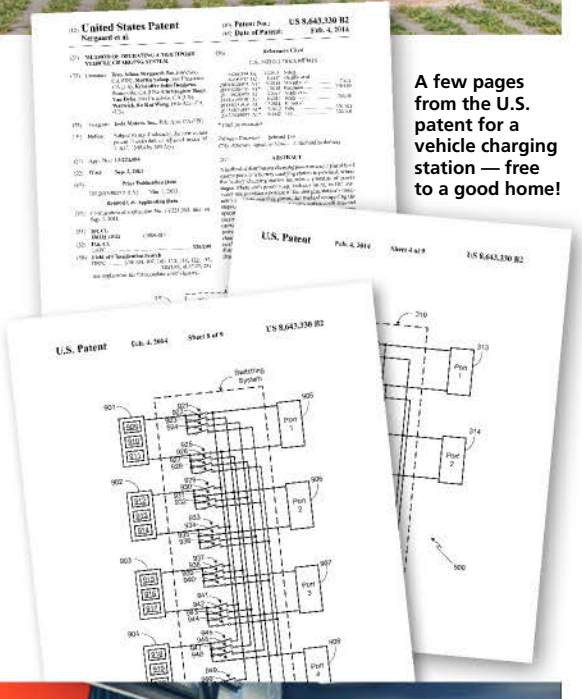
Fun fact: *B. ankarafensis* has a notable calling card: Instead of producing three clicks to attract a mate, the new species uses only two. This missing click got researchers' attention just in time. Although the froggies reside within the protected Sahamalaza–Îles Radama National Park, ongoing destruction of their habitat threatens their numbers, leading researchers to suggest a placement on the critically endangered list. Heeding their call could help save the species. —BRENDA POPPY

TOP: ERNIE WRIGHT (USRA)/GODDARD SPACE FLIGHT CENTER SCIENTIFIC VISUALIZATION STUDIO. BOTTOM: GONÇALO M. ROSA



Tesla electric cars "fill up" at a fast-charging station in Hawthorne, Calif.

Tesla's Perplexing Patent Giveaway



A few pages from the U.S. patent for a vehicle charging station — free to a good home!

Patents are the prizes of modern innovators, talismans of technological prowess, potential tickets to profits and power. So it came as a shock in June when Tesla Motors CEO Elon Musk released all the company's electric-car patents. Musk said he shared his patents for parts and processes merely to jump-start the slow-selling electric vehicle market, but some analysts and tech commentators weren't buying it. They saw Musk's move as a play to make Tesla's technologies — especially its charging stations — an industry standard. Many advocates hoped the release would mark the beginning of an end to brutal, litigious patent wars that stultify innovation. —MICHAEL FITZGERALD



Tesla CEO Elon Musk referenced a popular Internet meme when he titled the announcement, "All Our Patent Are Belong to You," a joke that carried through to the decor at Tesla headquarters in Palo Alto, Calif., where a giant poster replaced a wall of patents.

FROM TOP: TESLA; U.S. PATENT OFFICE; STEVE JURVETSON/CREATIVE COMMONS/FLICKR (2)

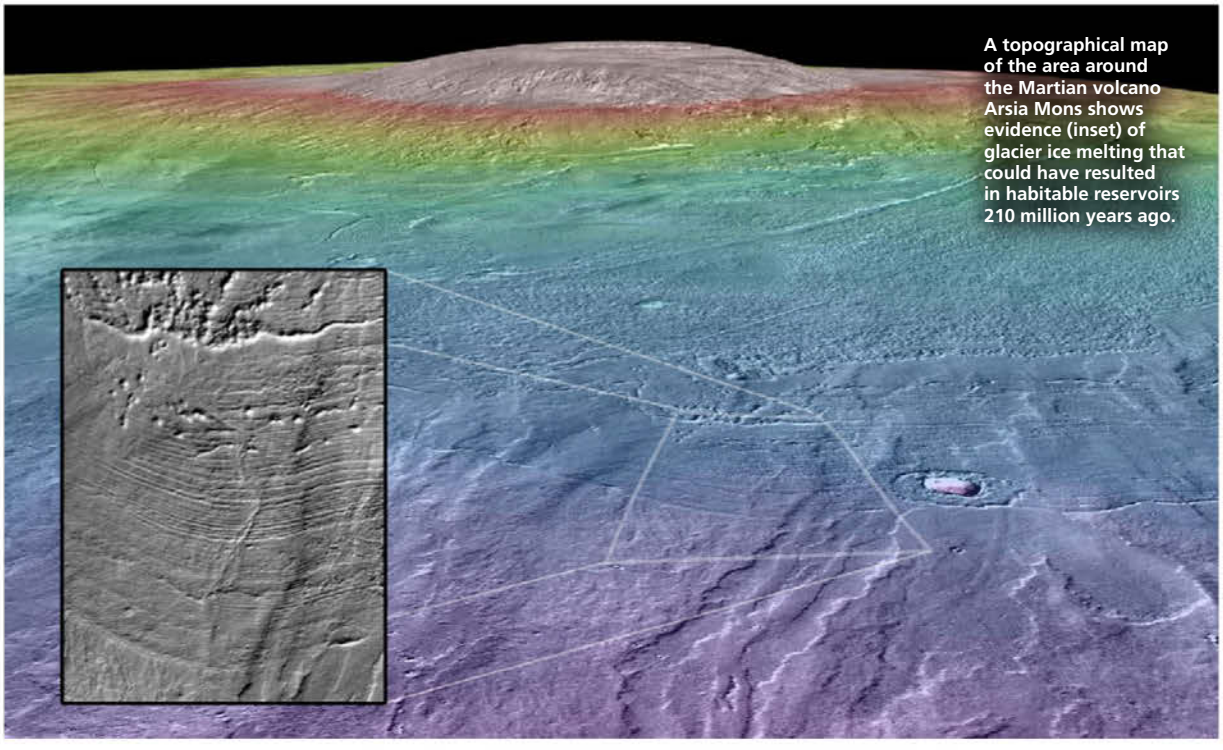
The Living Lakes of Mars' Recent Past

61

If life ever thrived on Mars (still a big if), it could've done so much more recently than scientists thought. In May, Brown University's Kat Scanlon presented geologic evidence that one of the solar system's largest volcanoes, the Red Planet's Arsia Mons, melted glaciers that were creeping across its surface some 210 million years ago, creating large oases for possible Martian microbes.

As the volcano vented lava beneath the thick ice sheets, it released huge quantities of liquid water within the glacier. Two reservoirs were each big enough to fill Utah's Great Salt Lake twice over.

The finding serves as tantalizing evidence that life-friendly environments existed on Mars much more recently than at the sites explored by NASA's rovers; those sites date back more than 2.5 billion years. Scanlon calculates that the water survived entombed in the ice for hundreds or even thousands of years — not long enough for new life to evolve, but certainly enough to form a habitat for any dormant microbes. — ERIC BETZ



A topographical map of the area around the Martian volcano Arsia Mons shows evidence (inset) of glacier ice melting that could have resulted in habitable reservoirs 210 million years ago.

Conception Code Cracked

62

Sperm meets egg: This rendezvous is crucial to procreation. But the actual mechanism behind fertilization has remained a mystery — until now.

British scientists published a study in April that identified a protein on the egg's surface — dubbed Juno, after the Roman goddess of fertility — that fuses with its male counterpart on the sperm cell, resulting in conception.

Using an artificial version of the protein Izumo, found on the surface of sperm, the team scoured the genetic sequences of millions of proteins until they found one that attached itself to Izumo, like a key in a lock. But the attraction between Juno and Izumo is weak, which explains why it took so long to ferret out the protein. Once fertilization occurs, the Juno protein virtually disappears from the egg's surface in about 40 minutes, ultimately preventing other sperm from entering.



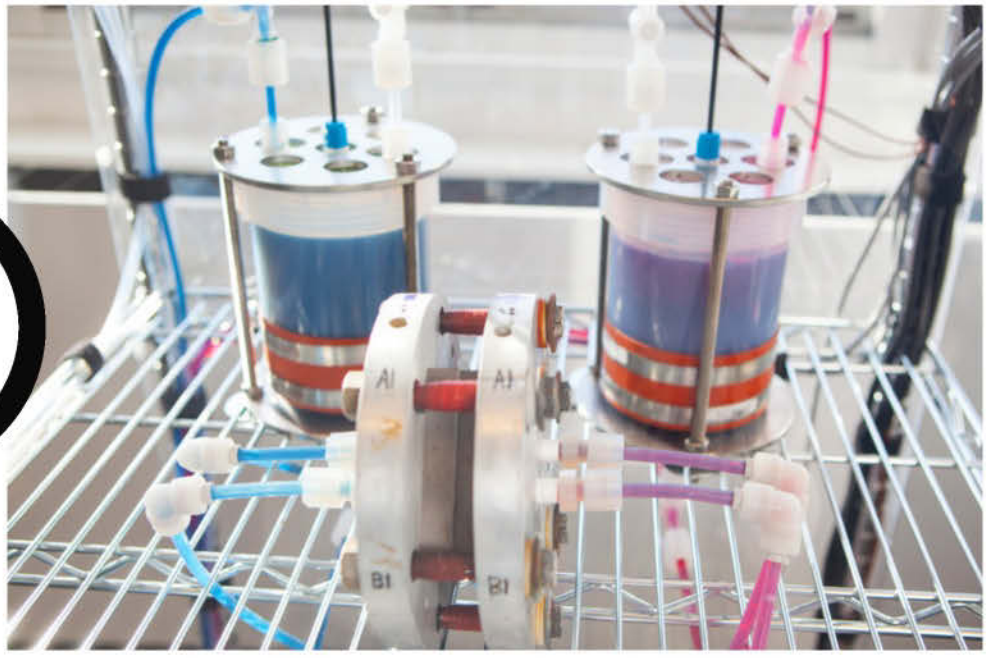
A specific protein is key to egg fertilization.

The discovery could result in a genetic test to detect if a woman's infertility is due to a defective Juno protein. It also may lead to contraception that blocks the action of these proteins, thwarting sperm. — LINDA MARSA

TOP: NASA/GODDARD SPACE FLIGHT CENTER/ARIZONA STATE UNIVERSITY/BROWN UNIVERSITY/JAY DICKSON. BOTTOM: WELLCOME TRUST/SANGER INSTITUTE

Bio-Inspired Battery Could Help Green the Grid

63



A prototype metal-free flow battery developed by engineer Michael Aziz (bottom) and colleagues at Harvard University relies on the electrochemistry of naturally abundant, small organic molecules to store electricity generated from renewable, intermittent energy sources.

The biggest hurdle to getting more electricity from renewable energy sources is the intermittency of the sun and wind — a problem that better batteries with less expensive materials could solve by storing large amounts of energy until needed. Now scientists think they may have the solution, with the help of a little organic chemistry.

Like conventional batteries, flow batteries store chemical energy and have a positive and negative electrode. When the battery is discharged, electrons and ions move from one electrode to the other, generating a current. Conventional battery materials are solid, while a flow battery's chemicals — often expensive because they're from rare metals — are liquid. To hold a large amount of energy, flow batteries need tanks capable of storing thousands of gallons of liquid. "If you want more energy, you just make bigger storage tanks," says Michael Aziz, an engineer at Harvard. "But the chemicals have to be cheap."

So Aziz, along with colleagues in the chemistry department, looked to nature for a more practical solution. They turned to quinones, a carbon-based class of chemicals that play an important role in animal and plant metabolism, moving electrons in the chemical reactions we use to store energy in our bodies. The researchers suspected that quinones also could move electrons in flow batteries. The quinone they picked, called AQDS, is already used in petroleum processing.

In January 2014, in the journal *Nature*, the researchers described a prototype flow battery that uses AQDS for one electrode. They showed that not only does it hold more energy than a conventional flow battery, but the cost of the quinone battery is much lower than other flow batteries — less than $27 per kilowatt-hour of energy stored, compared with $81. They're now working with a Connecticut company to develop a prototype system. —KATHERINE BOURZAC



Aziz's prototype would cost much less than other flow batteries.

BOTH IMAGES: ELIZA GRINNELL/SEAS COMMUNICATIONS

64

Quicker Quantum Boot-Up

Quantum computers — machines that make use of the strange properties of the subatomic realm — will be versatile and powerful, scientists hope, but today's versions take a painstaking six hours to boot up. Fortunately, in June, physicists at Germany's Saarland University reported in *Physical Review Letters* that they had devised a way to boot up experimental quantum chips within minutes, almost as quickly as a desktop computer.

Booting up took so long because quantum computer chips are extremely sensitive to changes in temperature, air pressure and electromagnetic interference, and each day researchers had to spend hours tuning the chips by hand. The trick was to come up with an algorithm that can systematically tune a quantum chip in just five minutes. The method should work for tomorrow's quantum computers, but for now, the algorithm, called Ad-HOC, will speed research by giving physicists more time to explore the nascent technology. —SHANNON PALUS

FROM QUBITS TO GADGETS

A new type of laser created by Dartmouth physicists could one day translate the photon-speak of quantum chips into signals that other gadgets — say, a computer screen — can understand. The laser's circuitry is made of the same superconducting material used in many quantum chips. This allows the quantum information to be encoded as particles of light, which could send a signal to another device. —SP



65

Can Vitamin D Prevent Alzheimer's Disease?

In August, researchers announced they had found a strong connection between low vitamin D levels and dementia, a deterioration of mental faculties affecting roughly 5.2 million Americans.

In the 1990s, U.S. researchers took blood samples from 1,658 participants age 65 or older as part of a cardiovascular study. About six years later, they followed up to see who had developed health complications, including symptoms of dementia and Alzheimer's disease, its most common form. Later, other U.S. scientists studying nutrition tested the original samples' vitamin D levels.

In the new study, a group of British researchers built upon both of those findings to determine whether there was an actual link between vitamin D levels and dementia. Their statistical analysis of the U.S. data connected insufficient vitamin D levels to a 53 percent increased risk of dementia and a 69 percent increased risk of Alzheimer's. The study, the largest of its kind, found that severe vitamin D deficiencies more than doubled the odds of developing Alzheimer's, a more substantial risk than previous studies had found.

These shortages might be because older skin converts sunlight into vitamin D less efficiently than younger skin. But experts aren't yet ready to recommend that older people load up on the sunshine vitamin: Researchers still need to determine whether higher vitamin D levels actually prevent the disease. —LINDA MARSA

LEFT: ALEXWHITE/SHUTTERSTOCK. RIGHT: IMAGE POINT FR/SHUTTERSTOCK

66



Facebook Experiments on Users, Faces Blowback

People don't often get riled up about research, but when Facebook toyed with its members' emotions without telling them, it stirred up plenty of feelings offline as well.

In June, researchers revealed in the *Proceedings of the National Academy of Sciences* that they had manipulated news feeds of unsuspecting Facebook users, influencing whether they felt positive or negative emotions. News of the experiment angered scores of users and privacy advocates. Before long, the journal backpedaled from its decision to publish the study with an "Editorial Expression of Concern," admitting that participants may not have known they were guinea pigs and did not get the chance to opt out.

The experiment, conducted over one week in January 2012, looked at "emotional contagion" — whether user emotions would affect other users' emotions online, as they do in person. Facebook used an algorithm to weed out posts with positive or negative words in the news feeds of 690,000 of its 1.3 billion users. Users who saw positive posts were more likely to post positive things than users who saw negative posts.

Privacy advocates demanded that the Federal Trade Commission investigate Facebook's research practices since it had experimented on human subjects without their permission. The FTC, per its policy, declined to comment on whether they were looking into it. But before the kerfuffle, Facebook quietly changed its data use policy to allow research on people — four months after finishing the experiment.

A university institutional review board probably would have signed off on Facebook's experiment, says Harvard Business School's Michael Luca, who has received approval to conduct similar covert experiments with other companies' websites. That's because informed consent is not needed for research that subtly manipulates people without overtly lying to them and causes only minor harm, he says.

Months after the news broke, Facebook said it would step up training for its scientists and have its senior researchers scrutinize proposed studies on content "that may be considered deeply personal," according to a blog post by Mike Schroepfer, Facebook's chief technology officer. "We were unprepared for the reaction the paper received when it was published and have taken to heart the comments and criticism." — MICHAEL FITZGERALD

TED SOQUI/CORBIS

NEW

"My friends all hate their cell phones… I love mine!" Here's why.

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911 Access	FREE	FREE
Long Distance Calls	No add'l charge	No add'l charge
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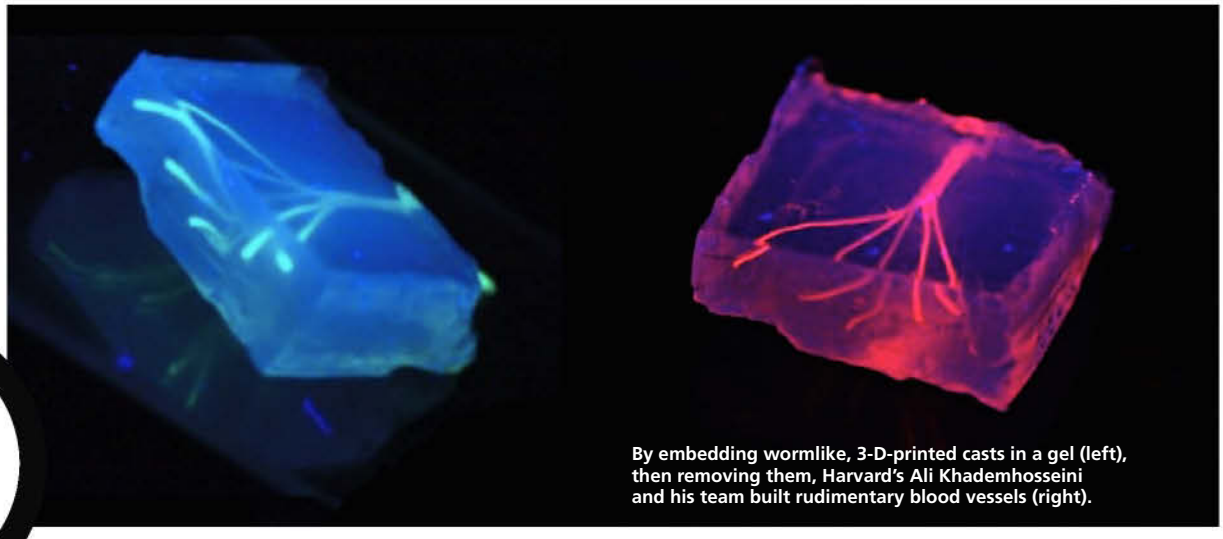
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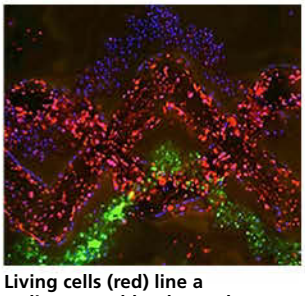
By embedding wormlike, 3-D-printed casts in a gel (left), then removing them, Harvard's Ali Khademhosseini and his team built rudimentary blood vessels (right).

67

Blood Vessels Via Printer

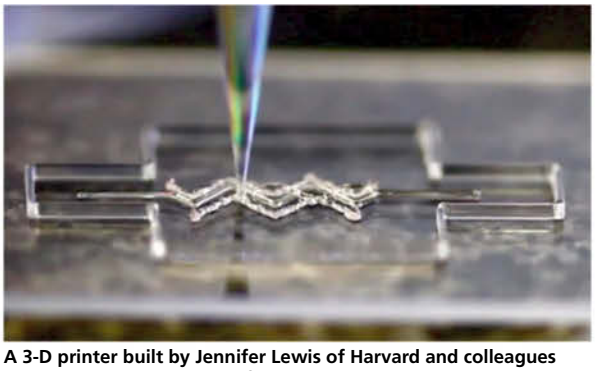
Could tomorrow's surgeons create customized replacement tissue for patients just by hitting print? Two teams of Harvard bioengineers made big strides toward that goal in 2014, reporting two new 3-D-printing methods that help construct rudimentary blood vessels.

Each year, thousands of people die waiting for tissue and organ donations, which are scarce. For that reason, tissue engineers are working to build replacements, and they've managed to do it for sheetlike tissues, like the skin and bladder. But replacement tissues for solid organs, such as the liver, heart or kidney, are tougher to construct because cells inside those tissues rely on a network of blood vessels that are difficult to replicate.



Living cells (red) line a rudimentary blood vessel created by Lewis' method.

In February, Jennifer Lewis' team reported printing tissue pieces infused with the beginnings of blood vessels. They used a custom-built 3-D printer and special inks containing extracellular matrix — the naturally derived material that the body uses to knit cells into tissues. The printer builds tissue, layer by layer. As the print heads move, they squeeze out inks like toothpaste from a tube. Those inks solidify into worm-shaped gels, some of which contain living cells. To print blood vessels, the researchers made the worm-shaped gels from a special ink that, strangely, melts as it cools. This allowed them to suction out the resulting liquid, leaving tunnels that they lined with other cells to form rudimentary blood vessels.



A 3-D printer built by Jennifer Lewis of Harvard and colleagues layers strand upon strand of biocompatible material, some containing cells, that they hope will form living tissue.

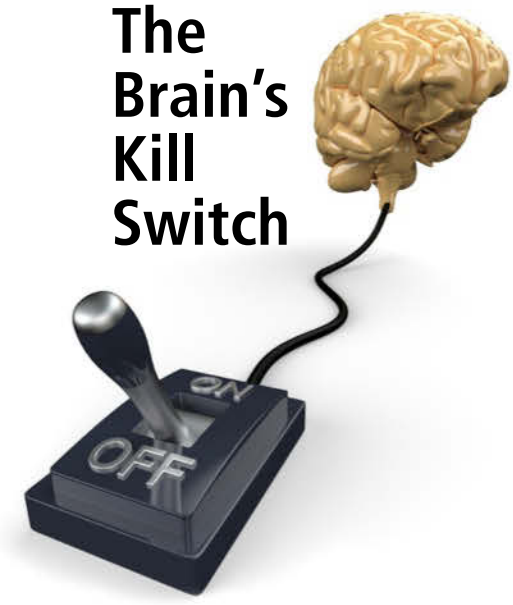
In May, a second team, led by Ali Khademhosseini, reported building tiny blood vessels that branch or merge in three dimensions, as blood vessels do in human organs. First, they 3-D-printed wormlike strands of a gel called agarose, each serving as a cast of a tiny blood vessel. Around those casts, they poured a cell-rich liquid that solidifies into a biocompatible gel. Then they carefully tugged or suctioned away the agarose casts, leaving channels that they lined with cells to create simple blood vessels.

For now, Lewis' team is working to create kidney and bone tissue mimics for drug safety screening. Khademhosseini seeks to hone his 3-D-printing process to make replacement blood vessels for individual patients. —LACY SCHLEY

FROM TOP: KHADEMHOSSEINI LAB; D. KOLESKY AND J. LEWIS, HARVARD UNIVERSITY/WYSS INSTITUTE/SEAS (2)

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The Brain's Kill Switch



In July, researchers reported a strange discovery that helped unlock one of the great mysteries of the mind: consciousness.

Mohamad Koubeissi, a neurologist at George Washington University in Washington, D.C., and colleagues were trying to identify seizure sources in an epileptic patient's brain by electrically stimulating different regions. To the researchers' surprise, the patient temporarily lost consciousness when they stimulated an area of the brain called the claustrum, located just below the cortex (the outer layer of the brain).

"It was striking," Koubeissi says. "All cognition and awareness appeared to become paralyzed, with a complete return to baseline once we turned the stimulation off." He repeated the experiment at least 10 times, with the same result.

The finding is the first to support a theory proposed by DNA co-discoverer Francis Crick shortly before the neuroscientist's death in 2004. He and colleague Christof Koch hypothesized that the claustrum is a "conductor of consciousness" that integrates our internal and external perceptions into coherent thoughts and ideas. If the claustrum's role in consciousness is confirmed by other studies, it could lead to new ways to induce consciousness in people trapped in comas or persistent vegetative states.

—CHRISTIE ASCHWANDEN

CLOCKWISE FROM TOP: STYLEUNEED.DE/SHUTTERSTOCK; CHRISTINA WARRINER; NATALLIA SHVED VIA UNIVERSITY OF YORK

69

Medieval Dental Plaque Offers Dietary Clues

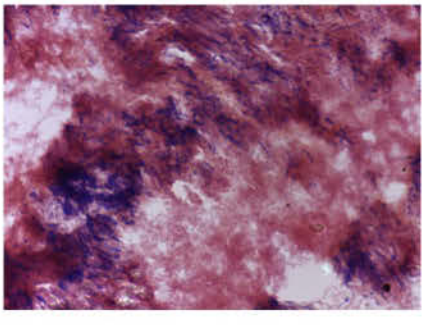
Let plaque sit on your teeth, and it will harden into dental calculus, the stuff your dental hygienist has to remove with a metal pick. But that crusty, calcified gunk actually preserves a wealth of dietary information, according to researchers studying four medieval skeletons from western Germany.

The University of Oklahoma's Christina Warinner and colleagues retrieved the genetic code of millions of microorganisms in the plaque, allowing them to determine what the person chewed or coughed up. They found thousands of bacteria species preserved in a rock-hard matrix of calcium.

The data, published in February, provide a snapshot of the medieval mouth — and more. "Calculi give you a window into health, diet and dynamic interactions with microbes," Warinner says.

Certain dietary staples haven't changed much, it seems. The plaque yielded pork and mutton biomolecules, along with wheat and microscopic remnants of a cabbage-like plant. "Some things, it turns out, are remarkably stable over time," Warinner says. —ANDREW CURRY





Top: Fossilized dental calculi coat the teeth of a jaw dating back to about A.D. 1100, found at a medieval site in Dalheim, Germany. Left: A sample of the calculus magnified 1,000 times reveals thousands of well-preserved oral bacteria. Red and purple staining differentiates two separate classes of bacteria.



Wild elephants, like this family, can apparently distinguish different human voices.

Elephants Recognize Humans by Voice

We've known elephants can recognize each other as individuals, but it turns out they can pick *us* out of a crowd, too, distinguishing ethnicity, age and sex by our voices.

Researchers studying 48 wild elephant families played recordings of voices from two ethnic groups with distinct languages in Kenya's Amboseli National Park. Male voices from the Maasai, who are often hostile to elephants, caused the animals to sniff the air for danger and retreat into a defensive formation. But when researchers played male voices from the more elephant-friendly Kamba, the pachyderms were much less perturbed. The elephants also weren't startled by voices of Maasai women and children, who don't hunt, revealing the animal's ability to discern subtle vocal differences.

"This has been one of the great aspects of studying elephants over the years, discovering that their cognitive abilities are extremely advanced in ways we may not have fully predicted," says University of Sussex behavior ecologist Karen McComb, whose study was published in March. —CARL ENGELKING

ER DEGGINGER/SCIENCE SOURCE



The canal would skirt the southern edge of Ometepe, an island formed by two volcanoes in Lake Nicaragua.

Proposed Nicaragua Canal Cuts Deep Divide

A century ago, Panama beat out Nicaragua to snag one of the biggest engineering projects of the age: a U.S.-backed canal that would link the Atlantic and Pacific oceans, creating a shorter trade route between East and West. In 2014 — the 100th anniversary of the Panama Canal's completion — Nicaragua made plans for its own interoceanic linkage, which would be triple the length of Panama's. If completed, the project could break Panama's long-standing monopoly on the shipping trade in the region — but at a severe ecological price.

The 175-mile-long canal, which was set to break ground in December, would cut a 1,700-foot-wide swath through two nature reserves, home to rare cloud forests and several endangered species of amphibians, birds and mammals. Designed to serve modern ships with larger hulls, the 90-foot-deep canal also would require dredging 65 miles across Lake Nicaragua, Central America's largest lake and a key source of drinking water.

"In the scientific community, we're quite worried," says biologist Jorge Huete-Pérez of the Central American University in Managua. In February, after Nicaragua announced that it would fast-track legislation in support of the project, Huete-Pérez co-authored a letter in the journal *Nature*. He warned that the canal, proposed by the Hong Kong Nicaragua Development Group (HKND), would disturb almost 1 million acres of rainforest and wetlands, and he urged the government to commission an independent environmental analysis of the project.

Instead, a spokesman for the Nicaragua Grand Canal Commission announced HKND would publish its own environmental assessment in November. With the company scheduled to break ground just a month later, the document's timing left little time for public review, critics protested.



HKND says it has hired environmental consultants to offset the canal's impact by restoring nearby degraded areas. Huete-Pérez is not reassured. "The logic of causing damage in the protected areas … to later compensate with reforestation is totally mistaken and has been amply refuted by the international scientific community," he says.

Even if the $50 billion project overcomes environmental protests, it must still contend with the challenges of Nicaragua's geology. The U.S. passed over Nicaragua when siting its 1914 canal because of its volcanic and seismic activity. Those geologic uncertainties remain a concern, says hydrologist Bob Stallard of the Smithsonian Tropical Research Institute in Panama City. And the new risk of climate change, which is fueling more intense hurricanes and severe droughts, could mean less than smooth sailing for ships navigating the waterway. — LUCAS LAURSEN

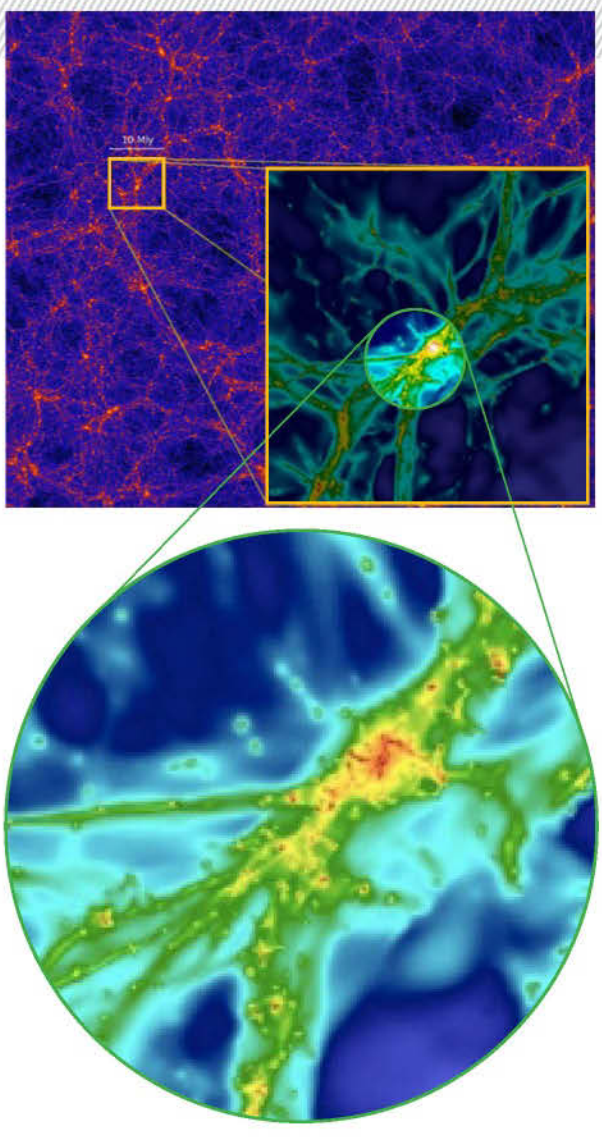


This 1870 map shows the route of an earlier Nicaragua Canal proposal.

FROM TOP: GUIZIOU FRANCK/HEMIS/CORBIS; ROEN KELLY/DISCOVER; BUYENLARGE/GETTY IMAGES

72

Quasar Illuminates Cosmic Web



Observations suggest invisible dark matter spans the universe, underpinning its entire structure. The gravitationally sticky stuff catches galaxies and causes gases to adhere to filaments, which stretch between the star clusters in a giant cosmic web. Astronomers in California and Germany studying quasar UM287 spotted an enormous strand of nebulous gas illuminated by the quasar's light, like an attic window lighting up otherwise unseen cobwebs. At about 2 million light-years long, the gas is thought to give form to one of the filaments of this cosmic web, the first time scientists have seen it. In this simulation, which accompanied the January study, the brighter colors in the upper left image show higher concentrations of dark matter. The inset shows the quasar's spotlight on the cosmic web, with darker blue representing the lowest density of gas and red representing the highest density. — BILL ANDREWS

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HIV Resurfaces in 'Mississippi Baby'

It seemed too good to be true — and it was. A baby born in Mississippi in 2010 to an HIV-positive mom was able to fight off the virus without medication. She had been given a short course of intense anti-retroviral medication at birth, followed by 18 months of continuous treatment. Then, for more than two years, she received no HIV medication. At age 3, when *Discover* featured the case in last year's Year in Science issue, the child remained infection-free. But doctors announced in July that the "Mississippi baby" showed detectable levels of the virus once again.

Doctors discovered the virus had returned when the child came in for routine blood work. Now the 4-year-old is back on anti-retroviral therapy. She is showing signs of improvement, says Hannah Gay, a physician treating the child at the University of Mississippi Medical Center. The girl's care team will watch for changes and plans to conduct more tests to find out why the virus suddenly reappeared. Meanwhile, a related federally funded trial, which aimed to replicate results in infected newborns, has been put on hold.
— LACY SCHLEY



Physician Hannah Gay will help oversee the 4-year-old girl's treatment at the University of Mississippi Medical Center.

TOP: S. CANTALUPO (UCSC)/JOEL PRIMACK (UCSC)/ANATOLY KLYPIN (NMSU). BOTTOM: UNIVERSITY OF MISSISSIPPI MEDICAL CENTER

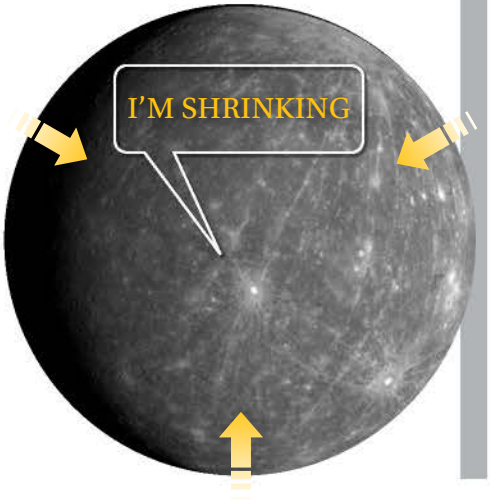
74

The Smallest Planet Gets Smaller

Scientists know from watching its surface activity that Mercury has shrunk over its 4.5 billion-year history. For decades, though, the question has been by how much. Observations from 1970s-era data suggested a shrinkage of 1 to 2 kilometers in radius throughout Mercury's history, while newer thermal models showed a more significant change over that time, about 5 to 10 kilometers.

Enter NASA's MESSENGER spacecraft, which produced a comprehensive survey of the smallest planet's surface features. The Carnegie Institution's Paul Byrne and his team used this planet-wide coverage to determine in March that Mercury's radius has shrunk between 4 and 7 kilometers over the past 4.5 billion years. "We were looking at this independently," says Byrne, "but it happened to be that the value we got is pretty much what the models had been saying all along."

Knowing the thermal models are spot-on is good news for planetary scientists working to understand Mercury's remaining secrets. "Now that we can show that the models are more robust than we had thought," Byrne says, "we can start looking at what the models are telling us about the interior of the planet, which we can't otherwise get." —KARRI FERRON



TOP: AIR IMAGES/SHUTTERSTOCK. BOTTOM: NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/CARNEGIE INSTITUTION OF WASHINGTON



75

From the Mouths of Babes

How does a babbling baby become a talking tyke? In June, researchers found part of the answer. Toward the end of the first year of life, they discovered, two brain areas begin coordinating to help babies figure out speech.

Until 6 or 7 months of age, babies can easily distinguish vowels and consonants from all languages. But by about 11 or 12 months, they've homed in on their native language — the one they've heard most — and started ignoring foreign sounds. Baby's first word follows soon after.

To learn how this transition into speech occurs in the brain, the University of Washington's Patricia Kuhl played babies in both age ranges separate recordings of their native tongue and a foreign one while measuring their brain activity.

When 7-month-olds heard either language, they showed similar activity levels in both the auditory system, which perceives sounds, and the motor system, which is involved in mimicking sounds. But 11- and 12-month-olds showed more activity in their auditory systems when they heard their native language. When they heard foreign words, on the other hand, it was their motor systems that lit up on the brain scan, indicating they had to work harder to imitate them.

According to Kuhl, these brain patterns show that once babies reach their first birthday, they not only pay closer attention to native words, they also prepare to start uttering them. At that age, the auditory system and motor system work together to set the stage for speech, Kuhl says.

Baby talk is an important part of that process, she adds. "The idea that a young child at 12 months can hear you say something and then know what to do to replicate that signal with their own mouths is remarkable," Kuhl says. —LACY SCHLEY

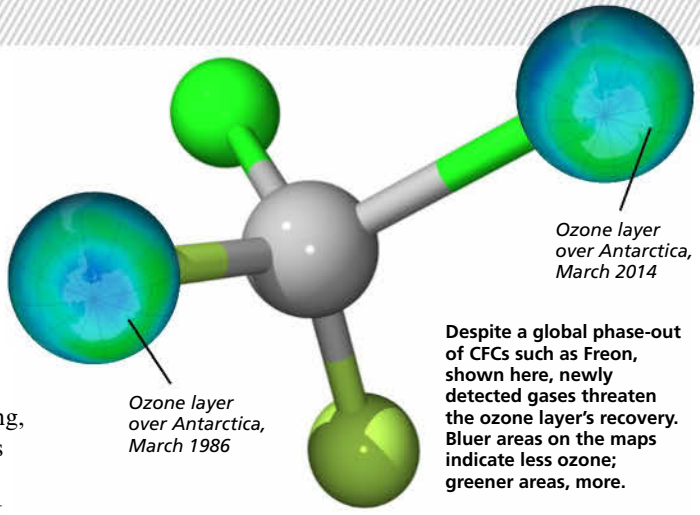
7 New Gases Deal Damage to Ozone Layer

76

The recovery of Earth's protective ozone layer has been hailed as an environmental success story. But the celebration may have been premature: Last spring, scientists discovered new ozone-destroying gases in the atmosphere.

The U.N.'s 1987 Montreal Protocol phased out almost all of the offending gases, and the ozone hole began to shrink. But in March, researchers with England's University of East Anglia reported finding four new ozone-depleting compounds in the atmosphere — three chlorofluorocarbons (CFCs) and one hydrochlorofluorocarbon (HCFC) — amounting to about 81,000 tons. In June, they found three more — two CFCs and one HCFC — bringing the total to seven.

And more could be discovered, says Johannes Laube, a co-author of the studies. "It could reverse the recovery trend," he says.



Despite a global phase-out of CFCs such as Freon, shown here, newly detected gases threaten the ozone layer's recovery. Bluer areas on the maps indicate less ozone; greener areas, more.

The emissions may have come from the production of insecticides, refrigerants or solvents, he says, either under the treaty's exemptions or through illegal use.

Overall levels of ozone-harming gases are still lower than before the ban, but since some disintegrate slowly, they'll continue destroying ozone for decades to come, Laube says. —JENNIFER DRAPER

2014 World Debut: New Species Series



Kamikaze Coitus

2014 World Debut: New Species Series

Antechinus arktos

Type of animal: Mouse-like marsupial

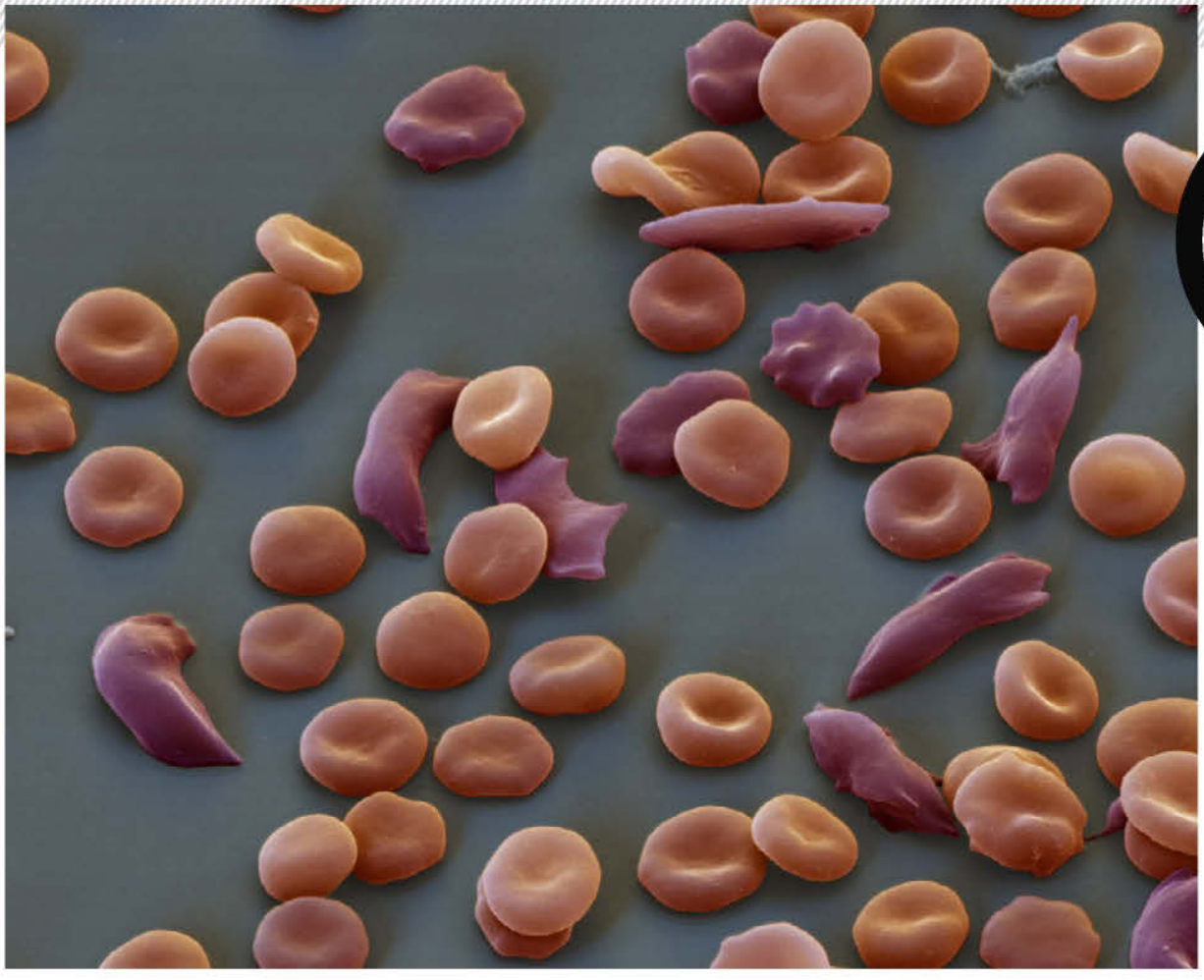
Description: Fur ranging from grayish-brown at head to orange-brown at rump; yellow markings around eyes; distinctive black tail

Home: Southeast Queensland, Australia



Fun fact: Finding a new mammal species is rare; finding one that kills itself through ardent and repeated sexual encounters is even more rare. *A. arktos* follows the mating patterns of others in its genus, copulating for up to 14 hours at a time and with multiple partners in order to ensure the survival of its lineage. Yet these fervent sexual escapades take their toll: Males' stress hormone levels increase dramatically during the weeks-long mating season, eventually causing their bodies to shut down completely. What a way to go. —BRENDA POPPY

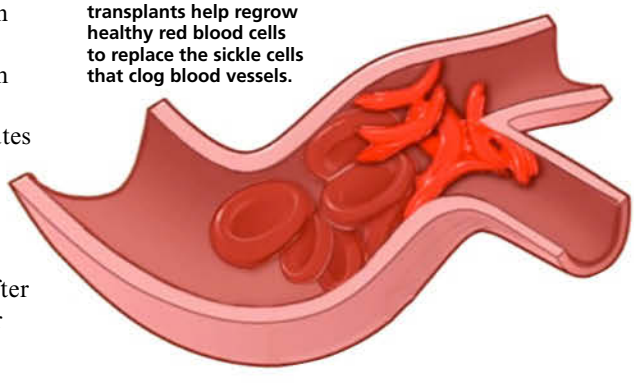
TOP: MOLECULE, TIM EVANS/SCIENCE SOURCE; OZONE IMAGES, NASA OZONE WATCH; ILLUSTRATION, DAN BISHOP/DISCOVER. BOTTOM: GARY CRANITCH/QUEENSLAND UNIVERSITY OF TECHNOLOGY



Sickle Cell Anemia Patients Get a Partial Reprieve

In sickle cell anemia, a single genetic mutation leads to abnormal, crescent-shaped red blood cells that clot in tiny blood vessels throughout the body, causing severe pain and eventual organ damage. The most common treatment is almost as debilitating: high-dose radiation therapy to remove the bone marrow that produces the abnormal cells, then a full bone-marrow transplant and a daily regimen of immunosuppressant drugs to keep the body from rejecting the transplanted marrow.

But in July, John Tisdale of the National Institutes of Health and his team reported that 26 of 30 adult sickle cell patients recovered after a far less grueling treatment: low-dose radiation, a partial bone-marrow transplant and an antibody to prevent immune attacks on the new marrow. After a few patients serendipitously stopped taking their meds, they remained healthy. The researchers then replicated those results in 15 patients. If larger studies pan out, adult patients will be one step closer to living a pain- and drug-free life. —LACY SCHLEY



Partial bone-marrow transplants help regrow healthy red blood cells to replace the sickle cells that clog blood vessels.

TOP: EYE OF SCIENCE/SCIENCE SOURCE. BOTTOM: NATIONAL INSTITUTES OF HEALTH

78



Plotting the Pattern of Emotion

Rock legend Tom Petty famously crooned that we just don't know how it feels to be him. Well, he might be wrong.

In June, neuroscientist Adam Anderson's team at Cornell University demonstrated that, though our feelings may seem unique, our brains process them using a similar pattern of brain cell, or neuron, activation — meaning we feel feelings the same way. To find that pattern, researchers monitored 16 participants' brain activity while presenting them with images and tastes; subjects then rated their feelings about each.

The team saw that when participants reported similar feelings, their brain cells fired in a similar sequence. Specifically, when more neurons fired in one direction along the sequence, participants reported positive feelings; when more neurons fired in the other direction, they reported negative feelings. Looking at a beautiful sunset or sipping a favorite cocktail, for example, evoked the same firing in the "positive" direction in each person.

This pattern of activity runs through vision- and taste-processing brain regions, indicating our subjective feelings are actually intertwined with perception. That is, our sensations are preloaded with emotions. According to Anderson, that upends the traditional belief that the brain perceives feelings first and then processes them in its emotional centers. Instead, seeing and feeling both happen at the same time.

Experts hope next to understand how this sequence differs in individuals with mental disorders, potentially leading to better treatment. — CARL ENGELKING

NERVE CELLS: SEBASTIAN KAULITZKI/SHUTTERSTOCK. FACES: LASSEDESIGNEN/SHUTTERSTOCK. ILLUSTRATION: DAN BISHOP/DISCOVER

79



Insect Lends Us Its Ears

Imagine a world where a fly on the wall could help Grandpa Joe *and* James Bond. In July, researchers announced that one fly's hypersensitive ears had inspired a cutting-edge hearing device.

Ormia ochracea, a parasitic fly species, needs extremely accurate directional hearing to target its prey: crickets. But the fly's ears are just half a millimeter apart — too close together to pinpoint a chirping cricket, which emits sound waves on a much larger scale, without some extra help. So *O. ochracea* relies on a seesaw-shaped mechanism to amplify the difference between what each ear hears.

Researchers re-created the fly's unique mechanism by constructing a 2-millimeter rectangular silicon device with a fulcrumlike pivot supporting a tiny beam, similar to a seesaw. Pressure from sound waves flexes and rotates the beam to create an electric signal that's processed to determine sound direction — the same way *O. ochracea* does.

"We believe the optimized version will perform better than any commercially available microphones using the same spacing," says study author Michael Kuntzman, who conducted the research at the University of Texas at Austin.

The device could help the elderly hear all the gossip at a dinner party or, with the funding the project got from the U.S. military, let spies hear secrets that could save lives. Kuntzman said the next step is to design a device that's durable enough for the rigors of everyday use. —CARL ENGELKING

CLOCKWISE FROM TOP LEFT: RON HOY; THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY; NASA/CXC/JPL-CALTECH/STSCI/NSF/NRAO/VLA

80

Tinkering With the Cosmos's Constants

Underlying the universe is a variety of physical constants, values not based on anything — they just are. This year, experiments refined two of them.

By measuring the relationships between electric current, voltage and the pull of gravity, scientists can determine a number of fundamental values, including Planck's constant. That's an integral value used in quantum mechanics that describes the relationship between energy and frequency. In January, physicists at the National Institute of Standards and Technology found a more precise value for Planck's constant — one that differs from the old one by just 22 parts in a billion.



Physicist Stephan Schlamminger tests one of the instruments behind the new Planck value.

Scientists also updated the gravitational constant, which governs how strongly massive objects attract each other. A team of scientists in Italy used a new experimental setup, measuring the gravitational pull between a cloud of cooled rubidium atoms and tungsten weights. (The new value differs from the old by less than a tenth of a percent.)

These new values won't change how we see the universe, but they may make our understanding more precise, and eventually that much deeper. —SARAH KOLLMORGEN

The Changed Constants

Planck's Constant

Old Value
6.626 069 57 x 10^{-34} Joules*second

New Value
6.626 069 79 x 10^{-34} Js

Gravitational Constant

Old Value
6.673 84 × 10^{-11} cubic meters by kilogram by seconds squared

New Value
6.671 91 × 10^{-11} m^3 kg^{-1} s^{-2}

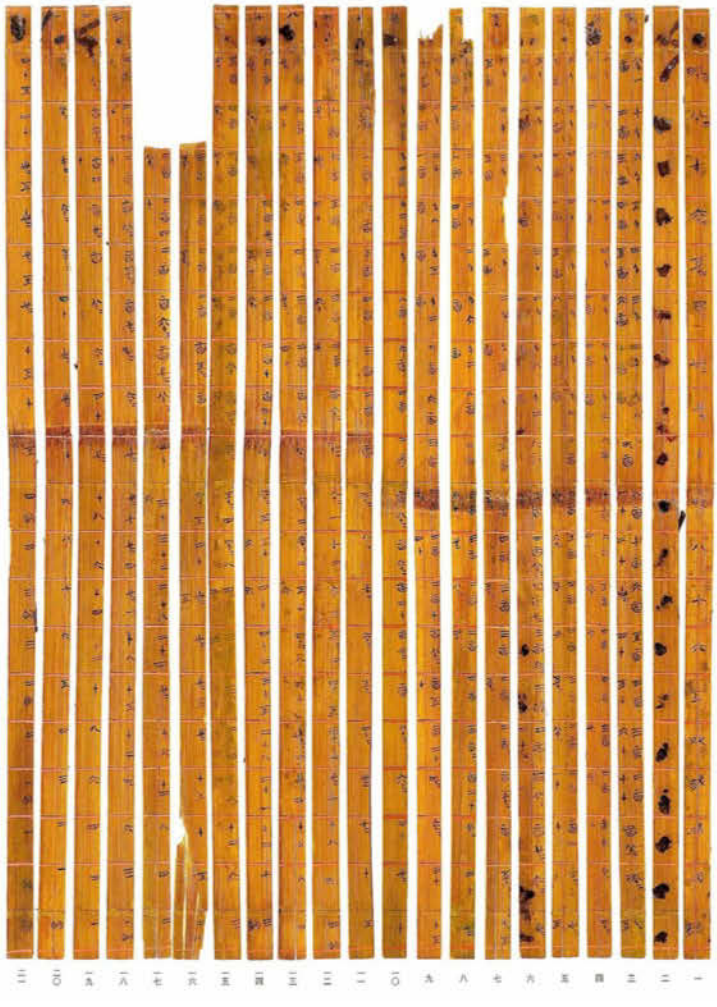
81

The Bamboo Calculator

By cleaning away mold from a set of 21 ancient bamboo strips, researchers have revealed a mathematical surprise: the world's oldest decimal multiplication table. Unlike the times tables that Western schoolchildren memorize, the bamboo table even multiplies fractions.

The bamboo strips are part of a roughly 2,500-strip collection that dates to 300 B.C., before China was unified. In January 2014, historians and paleogeographers at China's Tsinghua University announced that the calligraphy on them forms a matrix with rows and columns of numbers from ½ to 90 that, like modern multiplication tables, yield a mathematical product where they intersect.

Bureaucrats and businessmen would have used the table to quickly tally payrolls or taxes. No other ancient civilization multiplied numbers in this way, says paleogeographer Wen Xing of Dartmouth College: "It is an amazing discovery." —CONNOR WALTERS



The Tsinghua table places factors across the top row and down the far right column. From left to right, or from bottom to top, respectively, the values are ½, 1, 2 … 9, then 10, 20 … 90. The rest of the table shows the products of these factors.

82

Massive Viking Fortress Is First Found in 60 Years

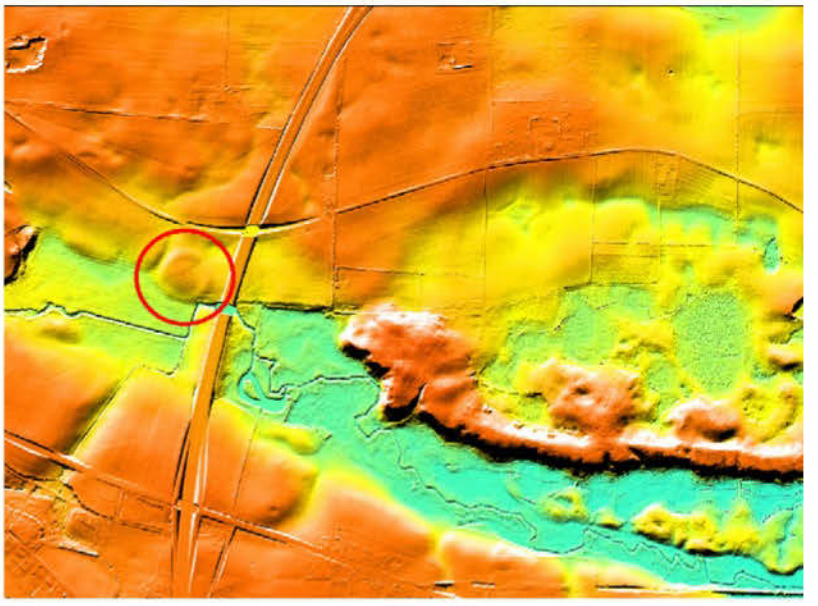
For centuries, a ripple of land in a farmer's field about 35 miles southwest of Copenhagen, Denmark, attracted little attention.

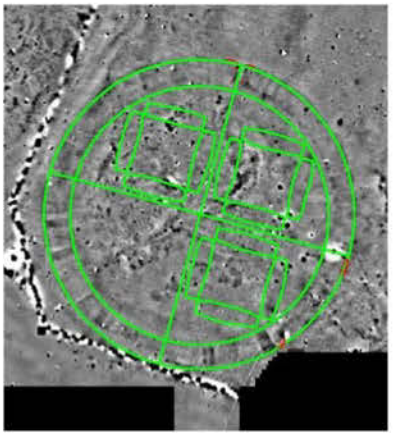
"We knew there was something out there, but we thought it was Iron Age, 800 years before the Vikings, so nobody was interested in it," says Nanna Holm, curator of the Danish Castle Center.

But Holm became curious about the site in rural Vallø when she came across new, more precise topography maps, which the Danish government created in 2009 and issued in 2012. She noticed that the



LEFT: RESEARCH AND CONSERVATION CENTRE FOR EXCAVATED TEXT/TSINGHUA UNIVERSITY. MAP: ALISON MACKEY/DISCOVER





A 2009 map (left), made by using lasers to measure subtle differences in elevation, reveals the circular shape of the fort (circled in red). In 2013, researchers created a finer-scale map of the site (above) and overlaid it with the floor plan of another Viking-era fortress that had already been excavated (in green) to compare scale.

new maps, created to identify areas at increased risk for flooding due to climate change, put subtle landscape variations into sharper focus.

What she saw — confirmed during a partial excavation last summer — was the outline of a massive Viking-era fortress. Measuring 475 feet in diameter, the fortress is perfectly circular, with four gates aligned to the four compass points — a uniquely Viking-age Danish style called Trelleborg. It's the first new Viking fortress discovered in more than 60 years.

In September, researchers dated the fortress to the 10th century, likely during the reign of Harald Bluetooth, the first king of a united Denmark. Details of that unification remain murky.

"New technologies mean new possibilities to answer old questions," says Holm. "Something happened during Harald's reign that created Denmark. We don't know how the state was created, but this fortress may help us answer that." —GEMMA TARLACH



Nanna Holm (above), curator of the Danish Castle Center, identified the charred remains of wooden posts and postholes during a partial excavation of the Vallø fortress last summer. The artifacts were dated to the 10th century, about the time Denmark became unified.



Although the fortress at Vallø has not been fully excavated, data suggest it is the Trelleborg style, named after a Viking-age fortification near Slagelse, Denmark (right).

CLOCKWISE FROM TOP LEFT: DANISH CASTLE CENTER/AARHUS UNIVERSITY (2); OJPHOTOS/ALAMY LIVE NEWS; THUE C. LEIBRANDT/CREATIVE COMMONS

83

Want a Better Brain? Sleep on It

Brain scientists know sleep improves memory, but why and how has been a tough nut to crack. Some evidence suggested brain cells form new connections during sleep; other evidence suggested sleep pares away existing connections.

Neurobiologist Wen-Biao Gan of New York University's School of Medicine and his team saw solid proof of the former. They taught mice a physical task and then watched their brains as the animals slept



— and saw neurons forming new connections.

To observe the changes, the team used genetically altered mice that produced a fluorescent protein gene that made certain neurons visible. The mice were divided into two groups: one that slept after learning a physical task and one that didn't. When Gan imaged their brains, he found mice that had slept developed more dendrites — the tiny filaments that allow neurons to communicate — than did sleep-deprived mice.

These observations, announced in June, demonstrate that deep, non-dreaming sleep helps create new brain-cell connections, at least, Gan says, when learning physical tasks.

—KAT MCGOWAN

84

Otherworldly Spring Found in High Arctic

For years, gullies on the surface of Mars have perplexed Red Planet specialists: How could such a frigid, desert-like environment have supported water?

Clues to this conundrum might lie in the Canadian High Arctic. In June, scientists announced they had found the world's northernmost perennial spring, whose head, channel and fan are similar to those on Mars.

"It's almost uncanny in resemblance," says Benoit Beauchamp, a geoscience professor at the University of Calgary, who discovered the spring with a colleague.

The Ice River spring, as researchers have dubbed it, intrigues scientists for more than its Martian connection. The spring's source remains a mystery. Since it's in a polar desert where the average temperature is minus 3.46 degrees Fahrenheit (minus 19.7 degrees Celsius), precipitation can't explain the cascade, gushing through the Arctic permafrost at nearly 137 gallons per second.

The next time the Canadian team treks back to the river, they'll be scanning the landscape for other bubblers. "Finding another spring like this would be a tremendous discovery," Beauchamp says.

—SARAH KOLLMORGEN



The gully formed by the Ice River spring, the northernmost bubbler ever found, bears a remarkable resemblance to this channel on Mars (inset).



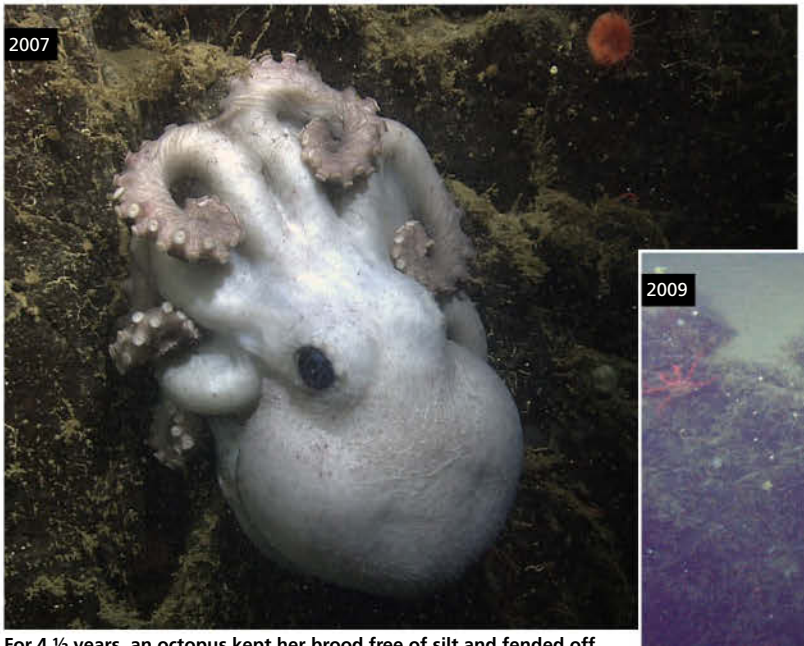
CLOCKWISE FROM TOP: KATHARINE ASHER/IKON IMAGES/CORBIS; STEPHEN GRASBY/GEOLOGICAL SOCIETY OF AMERICA; NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA; ALISON MACKEY/DISCOVER

Nature's Most Patient Mother

85

Nine months feels like an eternity to welcome a bundle of joy, but could you imagine 4 ½ years? That was the reality for one female octopus, *Graneledone boreopacifica*, and it's the longest known brooding period of any animal, reported biologists from the Monterey Bay Aquarium Research Institute in July. In 2007, researchers spotted the octo-mom in deep, frigid waters off California's coast. They returned 18 times, only to find the pale, famished mother right where they left her. Researchers believe that when the brood finally hatched, the mother died — a typical fate for new octopus mothers. — CARL ENGELKING







For 4 ½ years, an octopus kept her brood free of silt and fended off predators. Her perseverance gave her offspring, which hatched in 2011 (leaving behind egg cases, top right), an increased chance of survival: They were so well developed, they could already swim and hunt.

FROM TOP: MONTEREY BAY AQUARIUM RESEARCH INSTITUTE (3); MEHAU KULYK/SCIENCE PHOTO LIBRARY/CORBIS

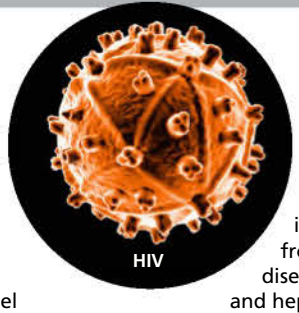
Hunting Down HIV Holdouts

86

HIV/AIDS is no longer a death sentence, thanks to now-standard treatments — particularly highly active antiretroviral therapy (HAART). But even with HAART, HIV can linger in brain and immune cells, reactivating years later to cause heart, kidney and neurological problems. Now, a new method that hunts down these HIV holdouts could lead to the first true cure for HIV/AIDS.

HIV, which infects about 35 million people worldwide, infiltrates cells, slips its genome into chromosomes and turns the cells into HIV factories. HAART keeps HIV from replicating, preserving the patient's immune function.

But to rid infected cells of HIV, Temple University researchers Kamel Khalili and Wenhui Hu customized a new gene-editing method called CRISPR to snip out the entire HIV genome without harming any human genes. The technique, announced in July, works in brain and immune cells where the virus hides, and it could one day protect people from future HIV infection and from other viral diseases, such as HPV and hepatitis B.



Researchers still need to test the treatment in animals, which could take several years. "We want to eradicate every single copy of [HIV] from the patient," Khalili says. "That will cure AIDS. I think this technology is the way we can do it." — KATIE BO WILLIAMS

87

Rare Good News for Endangered Pandas



Captive giant pandas like Ju Xiao, shown here with one of the triplets she gave birth to in July, are genetically healthy, but it's tough for her wild cousins to find a bamboo patch to call their own.

The giant panda's star turn in animated movies and nature shows has done little to bolster its protection. Decades of logging, as well as road and railroad construction, have shrunk the bear's habitat; just 1,596 wild pandas remain, according to the latest count. But in July, Chinese researchers reported some good news: By analyzing 240 of the iconic bears from four Chinese breeding centers — accounting for 64 percent of captive giant pandas — they found high levels of genetic diversity and little evidence of inbreeding at all but one of the facilities. "The captive population is genetically healthy," the team wrote. But there's a catch to releasing more pandas into the wild: There's little room left for them. Where's *Kung Fu Panda*'s Po when you need him? —APRIL REESE

2014 World Debut: New Species Series



Mite-y Singer

2014 World Debut: **New Species Series**

Litarachna lopezae

Type of animal: Deep-sea mite

Description: Microscopic member of widespread but relatively unstudied Pontarachnidae family

Home: The Bajo de Sico coral reef system off Puerto Rico



Fun fact: *L. lopezae*'s namesake is none other than pop icon Jennifer Lopez. According to Vladimir Pešić, the study's lead author, J.Lo's music kept the team upbeat while writing the manuscript for their paper.

While it is the deepest-living marine mite, found nearly 230 feet below the ocean's surface, its claim to fame is mainly in the name. —BRENDA POPPY

TOP: CHIMELONG SAFARI PARK/XINHUA PRESS/CORBIS. BOTTOM: VLADIMIR PEŠIĆ

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88



Nearby galaxy M82 was home to one of the closest type Ia supernovas in decades.

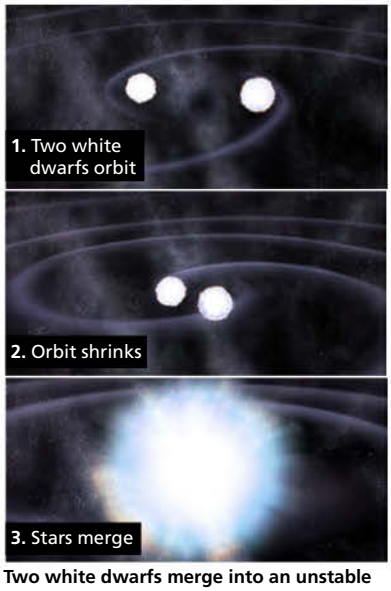
Stellar Explosion Illuminates Cosmos

In January 2014, astronomers watched a rare supernova light up and began filling in one of the most embarrassing gaps in their understanding of the universe.

The explosion, dubbed SN2014J, belongs to a class of supernovas called type Ia. These objects all apparently blow up the same way, allowing astronomers to use them as standard beacons for reckoning the size and structure of the cosmos. But nobody knows exactly how type Ia supernovas work, leaving the queasy possibility that those inferences are full of errors.

SN2014J is changing that. The star exploded in the neighboring galaxy M82, about 12 million light-years away, making it the nearest type Ia supernova in decades. It's close enough that researchers could confirm current theories indicating the supernova started out as a white dwarf — a small, collapsed stellar cinder. Details about the explosion specifically suggest that it occurred when one white dwarf collided with another.

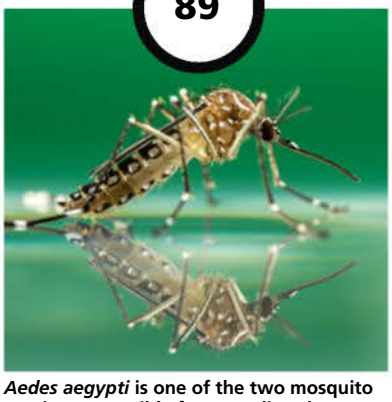
Collectively, the findings support the notion that type Ia supernovas suffer from "stellar amnesia," meaning that they "forget" the specifics of their earlier selves and become largely identical once they go off — just as astronomers hoped. Only in the counterintuitive world of cosmology can amnesia lead to greater awareness. – COREY S. POWELL



Two white dwarfs merge into an unstable star that explodes as a type Ia supernova.

TOP: ADAM BLOCK, MT. LEMMON SKYCENTER, UNIVERSITY OF ARIZONA. BOTTOM: NASA/CXC/M.WEISS

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***Aedes aegypti* is one of the two mosquito species responsible for spreading the chikungunya virus across the U.S.**

Chikungunya Virus Arrives in the U.S.

In July, the Centers for Disease Control and Prevention confirmed that chikungunya, a mosquito-borne virus recently introduced to the Western Hemisphere, had arrived in the United States.

Chikungunya has no specific treatment and causes fever and severe joint pain. First found in Africa and Asia, the disease spread to Europe, then the Caribbean islands, where the first locally transmitted case in the Western Hemisphere was reported in late 2013. In 2014, the disease traveled rapidly, reaching the United States and about 30 other countries.

As of Oct. 27, the CDC reported nearly 760,000 suspected and more than 14,000 confirmed cases in the Americas and the Caribbean, with almost 1,500 in the United States. Although most of the U.S. citizens caught the virus abroad, on July 17, a Florida man became first chikungunya victim to contract the virus at home. Eleven more local cases have followed as of late October. So far, all are isolated to the Sunshine State.

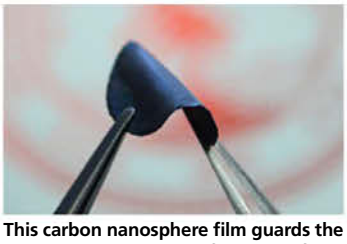
The two mosquito species spreading chikungunya in the Western Hemisphere, *Aedes aegypti* and *Aedes albopictus*, are also responsible for dengue fever's spread.

There's no known cure for chikungunya, but it usually isn't fatal and clears up in about a week in most people. — CARL ENGELKING

90

Lithium's Power Unleashed

If you're sick of your cell phone's pathetic battery life, Stanford University researchers announced in July that they may soon have a solution: a pure lithium battery.

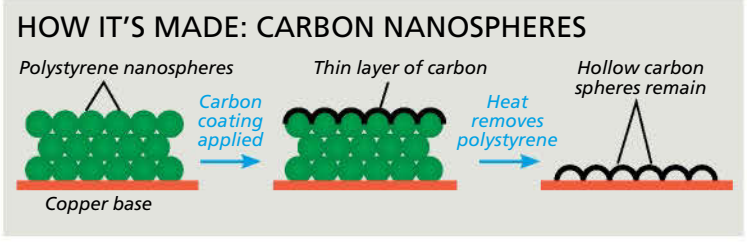


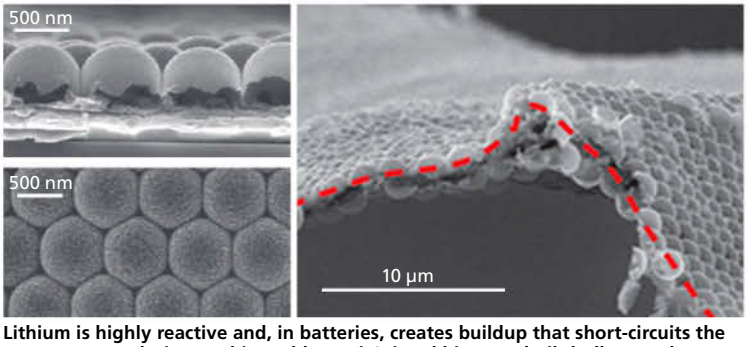
This carbon nanosphere film guards the lithium battery's anode from harmful chemical reactions that would render the high-energy battery useless.

Lithium batteries have three main parts: the anode that discharges the electrons, the cathode that absorbs them and an electrolyte that carries ions between the two. Today's batteries use graphite anodes, but lithium anodes are ideal because the metal is lightweight and stores high energy levels in a small space. Past lithium anode attempts failed because lithium is highly reactive, forming fingerlike structures that build up on the anode and short-circuit the battery. Lithium anodes also react with liquid electrolytes to heat up and wear out the battery.

To overcome this problem, engineer Yi Cui and his team built a minuscule, hollow carbon sphere on top of the anode. The honeycomb-like structure, roughly 1,000 times smaller than the radius of human hair, acts like a hat for the lithium anode, protecting it from buildup.

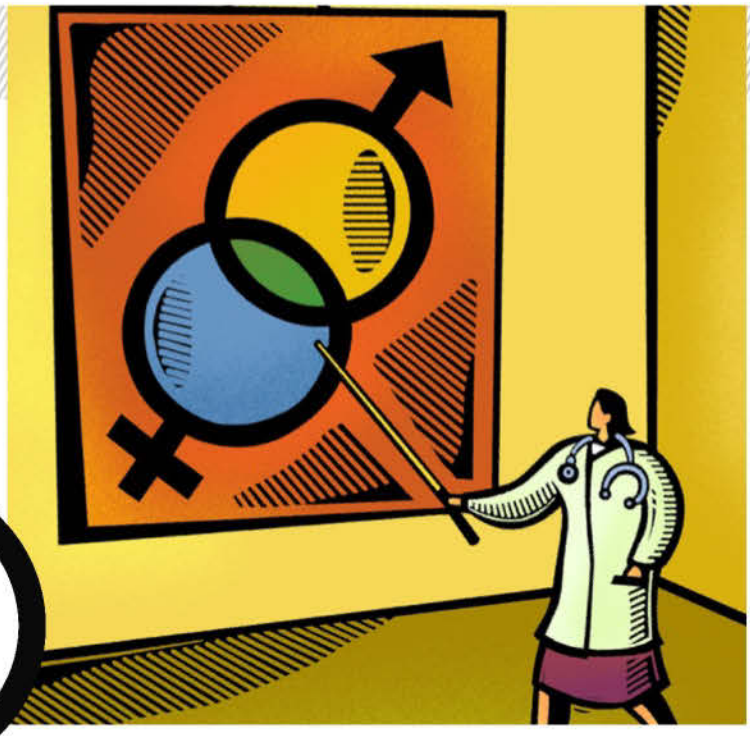
Despite the exciting potential, Cui said it will take three to five years before this product could be ready to store energy for the electric grid, solar cells and wind farms. — AMY KRAFT





Lithium is highly reactive and, in batteries, creates buildup that short-circuits the system. As a solution to this problem, Yi Cui and his team built hollow, carbon nanospheres to act as a protective barrier between the liquid electrolytes and the lithium anode.

LEFT COLUMN: ALEX WILD. RIGHT COLUMN: YI CUI/ADAPTED BY PERMISSION FROM MACMILLAM PUBLISHERS LTD: NATURE NANOTECHNOLOGY 9, 618-623 (2014)



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Top-to-Bottom Sex Bias in Labs Skews Results

Gender and sex imbalance infects science at every level, from the demographics of lab personnel right down to the tissue samples used in experiments. This bias is skewing research results in ways that threaten public health, warn top officials at the National Institutes of Health (NIH).

"It's a real blind spot that's resulted in huge gaps in our knowledge," says Janine Clayton, associate director of Research on Women's Health at NIH. "Too often we rely on male animals, even when studying diseases that are more prevalent in women."

Traditionally, researchers avoided using female animals because they worried hormonal fluctuations and reproductive cycles would skew results. But because women respond to medications and develop some diseases differently than men, researchers need to include female lab animals, tissues and cells in their experiments, according to a *Nature* commentary Clayton co-wrote in May.

Even a scientist's gender can compromise research, according to a Canadian study published in April. The paper found that the mere presence of men in the lab induced such intense stress in rodents that it altered how the animals reacted to pain.

"Males can be perceived as dangerous, and stress can muffle pain responses," says Jeffrey Mogil, the study's lead author and a pain researcher at McGill University in Montreal. "This can affect a very large set of experiments. What's amazing is that this is 2014, and we didn't know about this until now." —LINDA MARSA

92

A Jolt for Dull Thoughts

Humans are unique among the animals in our ability to mentally detach from our surroundings and purposely look inward. But sitting in quiet contemplation turns out to be much tougher than it seems, University of Virginia and Harvard researchers reported in *Science* in July.

The researchers instructed 146 college students to sit in an austere laboratory for up to 15 minutes without cell phones, books or other distractions, entertaining themselves with only their thoughts. Most of them couldn't do it, and reported being bored. Even in the presumably cozier environs of their home, volunteers in another experiment found their own musings painfully dull.

Then, when researchers left people alone in a room with a device that let them jolt themselves with mild electric shocks, they discovered that most men are so desperate for distractions that they would rather zap themselves. Two-thirds of men in the study, compared with 25 percent of women, chose to shock themselves rather than sit quietly. One man even pressed the button 190 times.

Lead author Tim Wilson, a University of Virginia psychologist, doesn't yet know why we get sidetracked so easily, but he doesn't think our social media addictions or even testosterone-addled male brains are entirely to blame. The ability to gaze inward may be an integral part of the human condition, but so is our inability to be alone, he says: "Because we're so attuned to be alert to danger, there is something about the human mind that finds it hard to turn in on itself." —LINDA MARSA



TOP: BULL'S EYE/IMAGEZOO/CORBIS. BOTTOM: COLIN ANDERSON/CORBIS

Safety Lapses Lead to CDC Lockdown



July's anthrax scare at the CDC's headquarters closed 23 labs for weeks.

In July, nearly two dozen government laboratories were locked down after more than 80 employees at the Centers for Disease Control and Prevention in Atlanta were potentially exposed to live anthrax bacteria. A subsequent internal investigation revealed a systemic pattern of safety lapses at the nation's top health agency. Investigators found four other incidents in the past decade when deadly pathogens were mishandled, including an event in March when a sample of the avian flu strain H5N1 was contaminated with a more lethal strain and accidentally shipped to a USDA lab without proper protections.

The agency moved swiftly, imposing a moratorium on the 23 labs transferring certain dangerous materials until they passed stringent safety inspections. The CDC also set up a panel of 11 independent experts to address lax procedures.

Although no one was sickened in the anthrax incident, the probe found numerous missteps, including that the bacteria were stored in unlocked refrigerators in unrestricted hallways. In the case of the H5N1 flu virus, shortcuts in the lab led to cross-contamination with the other virus.

A dozen labs had reopened by August, the same month the new safety panel started hammering out ways to improve oversight. "Safety protocols were in place, but they weren't followed," says Benjamin Haynes, a CDC spokesman. "We take it very seriously." —LINDA MARSA

2014 World Debut: New Species Series

Waiomys mamasae

Type of animal: Semi-aquatic, insectivorous rat

Description: Dense gray-brown fur; small eyes and ears; long tail equipped with whiskers to aid in swimming

Home: Sulawesi Island, Indonesia



Fun fact: Although physically similar to water rats from nearby countries, *W. mamasae* is genetically more similar to the land rats of Sulawesi — meaning it evolved the same traits as other water rats without descending from the same line, via convergent evolution. It represents not only a new species, but an entirely new genus. Yet it's not new to everyone: The people of Mamasa (the species's namesake) have long used the rat as a talisman to ward their homes against fire. —BRENDA POPPY

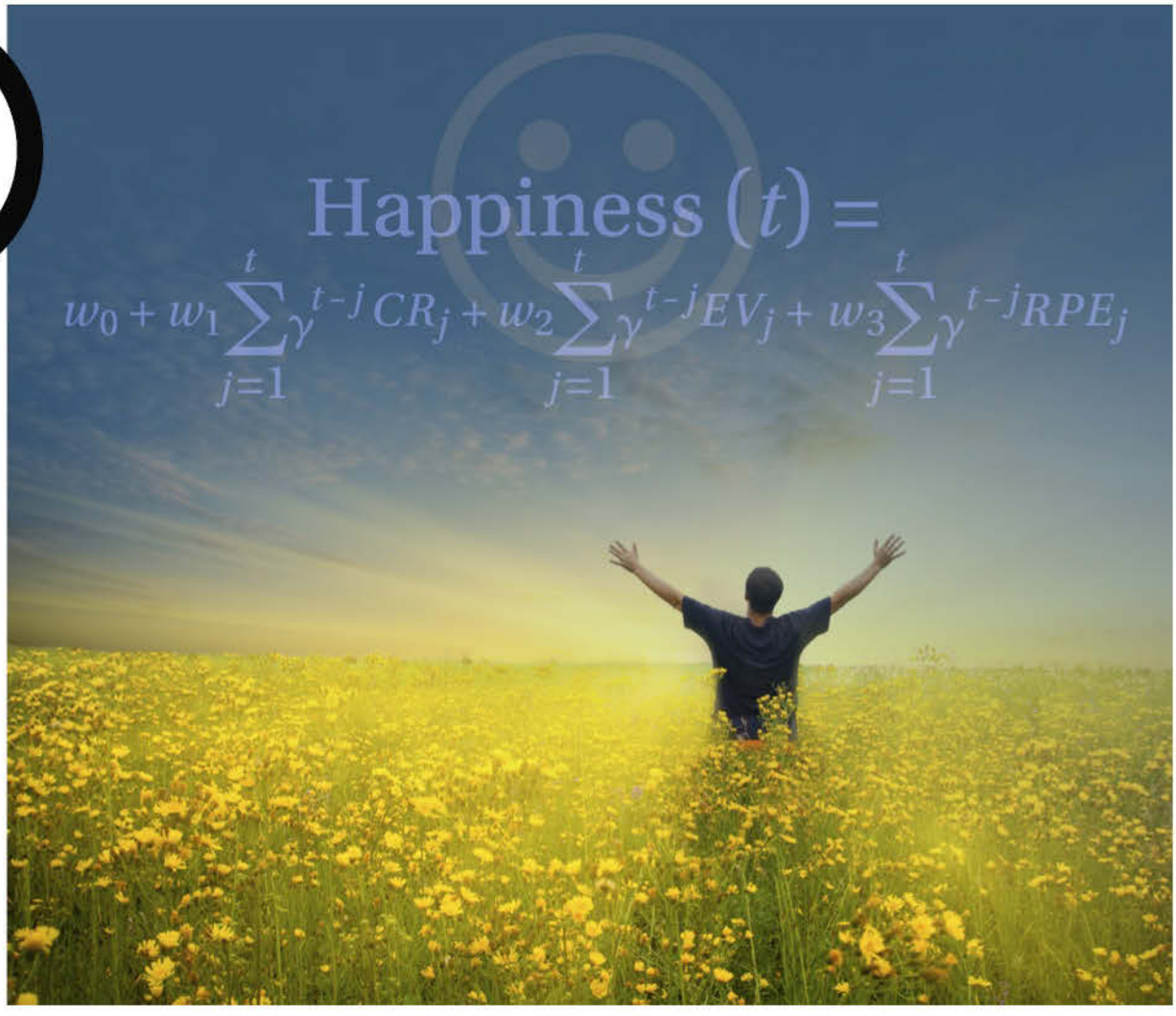
2014 World Debut: New Species Series



Holy Water Rat, Man

TOP: PADLOCK, ISTOCK/THINKSTOCK; DAVID GOLDMAN/ASSOCIATED PRESS/CORBIS. BOTTOM: KEVIN C. ROWE/MUSEUM VICTORIA

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There's a Happy App for That

If you want to be happy, it's time to lower your expectations.

Researchers from the University College London in August created a mathematical formula that accurately predicted the rise and fall of people's happiness. We become happy, the equation indicates, when events exceed our expectations.

"If you have lower expectations, and you get a reward, you'll be happier about it," says study co-author Robb Rutledge.

To build the formula, Rutledge's team asked 26 people to undergo a functional MRI while playing a gambling game that required them to place bets, spin a wheel of chance and collect as many points as possible. Subjects rated their happiness every few rounds as they won or lost points. Then, to ensure their results in the lab weren't a fluke, researchers released a smartphone app that simulated the lab experiment cheaply and on a larger scale.

"Our expectations were pretty low for the app because we were worried that no one would play it," Rutledge says. However, more than 18,000 people participated in the app experiment, and the algorithm's predictive powers were confirmed. The app's expectation-shattering performance, not surprisingly, made researchers quite happy.

The algorithm could help diagnose mental disorders, such as depression, by comparing people's happiness levels to what the algorithm predicts, Rutledge says.

—CARL ENGELKING

EQUATION: ROBB RUTLEDGE, ET AL./PNAS/DOI:10.1073/PNAS.1407535111/AUGUST 19, 2014. PHOTO: CHESTERF/ISTOCK/THINKSTOCK

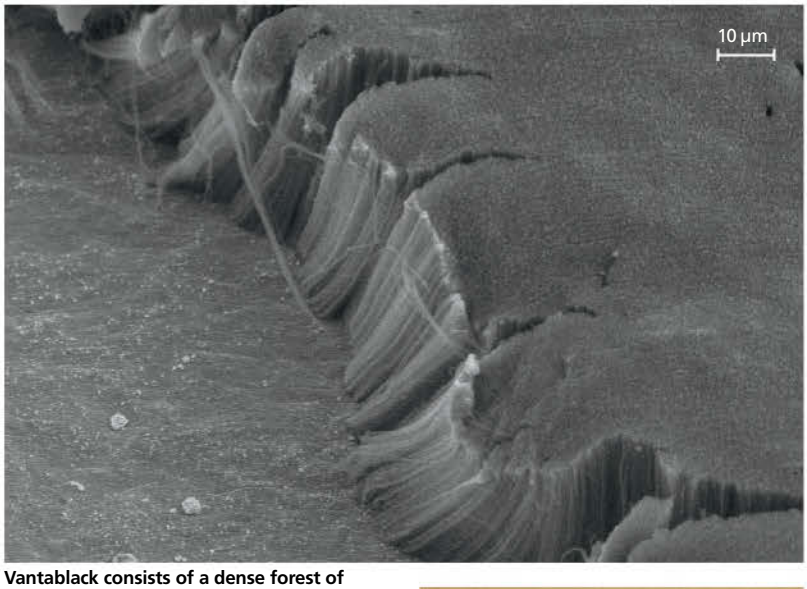
95

Vantablack Is the New Black

Imagine the darkness of a black hole right here on Earth. In July, British company Surrey Nanosystems publicly released a material so black that it absorbs 99.96 percent of light, making it the most absorbent thing on Earth.

This outrageously obsidian material, called Vantablack, owes its darkness to a set of vertically aligned carbon nanotubes — each about 10,000 times thinner than a human hair — that are suspended in plasma and coated directly onto materials like aluminum foil. The nanotubes are packed so tightly that incoming light particles bounce around between them until the nanotubes absorb them.

Vantablack also has other useful qualities: It withstands the stress from launching a rocket into space, long-term vibrations and extreme temperature fluctuations. Defense contractors are especially eager to get their hands on the material, no doubt due to its ruggedness and potential for stealth weaponry. More peacefully, astronomers hope it can improve telescope accuracy by reducing stray light within their instruments. — AMY KRAFT



Vantablack consists of a dense forest of carbon nanotubes suspended in plasma that's coated on materials like aluminum (magnified above) for easy application.



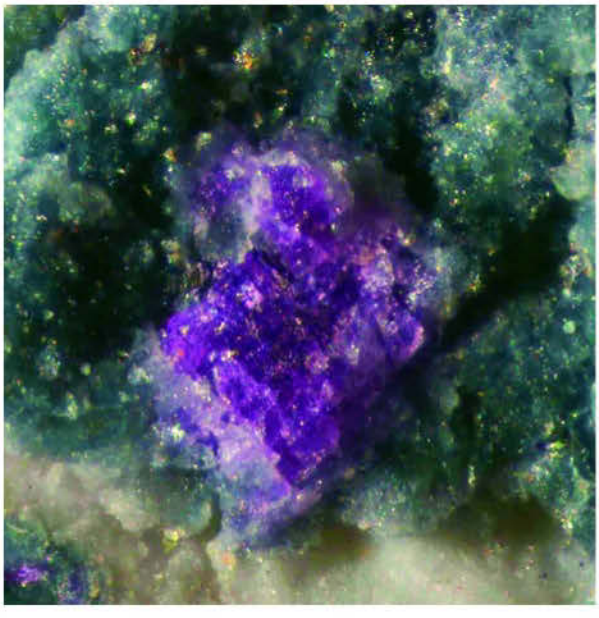
Via its system of carbon nanotubes, Vantablack absorbs 99.96 percent of light.

96

A Rock Like No Other

When a Western Australian mining company stumbled across some strange-looking purple-pinkish rocks in 2006, it handed them over to geologist Peter Elliott of the South Australian Museum. Eight years of analysis later, Elliott announced in April that it was a previously unknown mineral, which he dubbed putnisite, after mineralogists Christine and Andrew Putnis.

Putnisite has both style and substance: The shimmering mineral has an otherworldly look, and while most new minerals are chemically or structurally related to other known minerals or synthetic compounds, putnisite is unique on both fronts. — SARAH KOLLMORGEN



Putnisite combines the elements strontium, calcium, chromium, sulfur, carbon, oxygen and hydrogen in a novel way: $SrCa_4Cr_8^{3+}(CO_3)_8SO_4(OH)_{16} \bullet 25H_2O$.

FROM TOP: SURREY NANOSYSTEMS (2); P. ELLIOTT, ET AL.

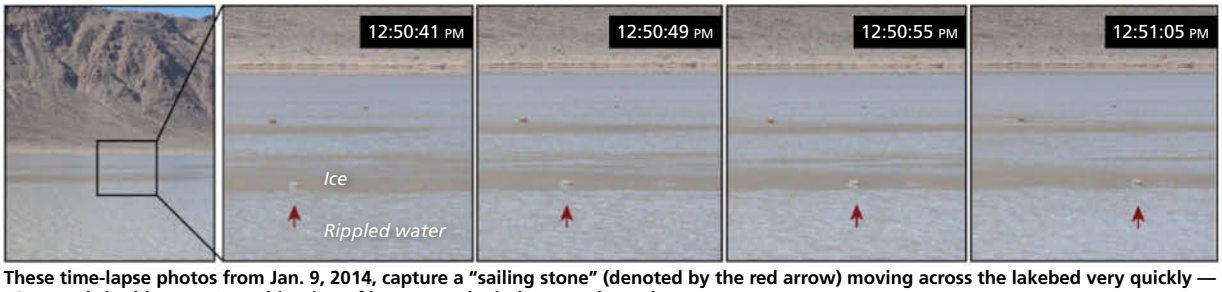
97



Death Valley's 'Sailing Stones' Riddle Solved

Death Valley National Park is home to a natural wonder that's baffled scientists for decades: large rocks that mysteriously trudge across a barren lakebed, leaving trails in their wake. In August, researchers announced they had caught the "sailing stones" moving on camera, thus solving the riddle.

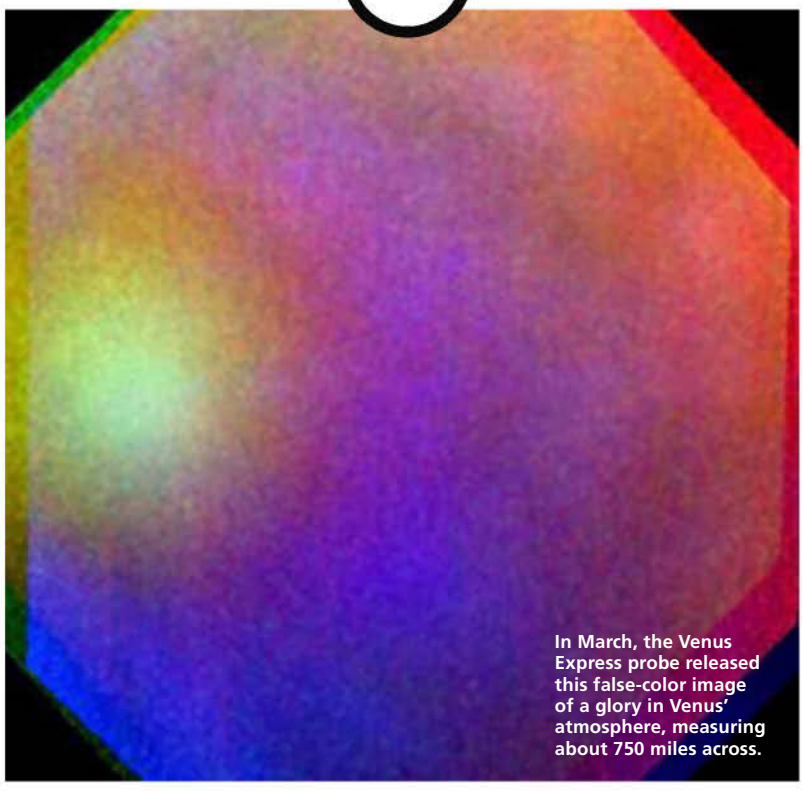
According to data collected from a weather station, GPS-embedded rocks and time-lapse photography, a perfect balance of sun, rain, wind and ice sets the rocks in motion. When the sun's heat broke apart ice that had formed atop a pond, the wind pushed the large, yet thin, sheets of ice into the rocks. Ice accumulated behind the stones, providing the push necessary for the rocks to "sail." —CARL ENGELKING



These time-lapse photos from Jan. 9, 2014, capture a "sailing stone" (denoted by the red arrow) moving across the lakebed very quickly — 18 seconds in this case. A combination of ice, sun and wind causes the rocks to move.

TOP: THOMAS DRESSLER/IMAGEBROKER/CORBIS. BOTTOM: RICHARD D. NORRIS, ET AL., PLOS ONE/DOI:10.1371/JOURNAL.PONE.0105948 AUG. 27, 2014

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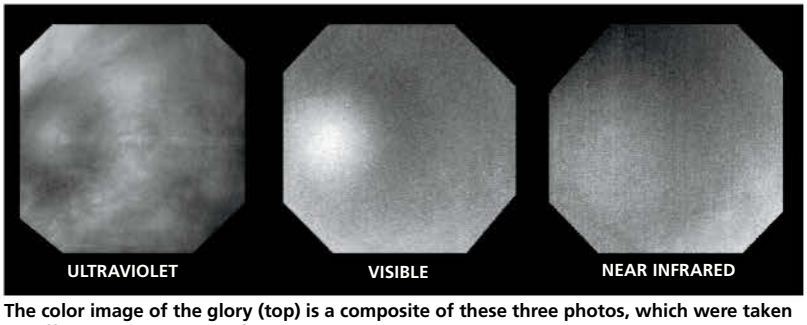


In March, the Venus Express probe released this false-color image of a glory in Venus' atmosphere, measuring about 750 miles across.

Venus Glory Reveals Cloud Qualities

That rainbow circle of light you might glimpse in the sky out an airplane window is known as a glory. For the first time, astronomers have fully imaged one on another planet.

Glories occur at a point in the sky opposite the sun when light scatters off tiny liquid particles, usually water in our clouds, refracting into rings. After analyzing this view of a glory on Venus — combining three wavelengths into a false-color image — astronomers were surprised to learn that the planet's clouds aren't pure sulfuric acid after all, but may include iron chloride and pure sulfur. — KARRI FERRON



The color image of the glory (top) is a composite of these three photos, which were taken at different wavelengths of light during the phenomenon.

VENUS GLORY: ESA/MPS/DLR/IDA. NOSE: P. LOENICKER/DOC STOCK/CORBIS

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The Nose Knows More Than We Thought

From roses to rainstorms to rotten eggs, our noses pick up thousands of scents every day. But just how many smells can we discern? Try a trillion — far more than once thought.

For decades, the number of scents the average person could distinguish was said to be about 10,000, an unverified estimate that smelled fishy to some researchers.

"We decided to do some experiments to replace the number with a more realistic one," says neurobiologist Andreas Keller of Rockefeller University.

Keller's team, which published the findings in March, had 26 volunteers sniff 520 odor "cocktails." Each was a different blend drawn from 128 distinct odor molecules. Participants were able to distinguish between even highly similar mixtures. Extrapolating from these findings, Keller estimates the average person can detect at least 1 trillion different smells, and probably far more. — APRIL REESE

100

Meet the Exoplanet Class of 2014

Another year, another amazing haul of exoplanets — worlds around other stars. The known total doubled to over 1,800, and headlines trumpeted several exciting, groundbreaking firsts. The numerous alien-world oddities that cropped up expanded our limited, solar system-centric perspective on nature's creativity. Just have a look at some of the "stars" of the Exoplanet High Class of '14!

— ADAM HADHAZY



OGLE-2013-BLG-0341LBb

Biggest trendsetter

This mouthful of an exoplanet stands as the first approximately Earth-size world, with an Earth-like orbit, in a double-star system. Before, astronomers had no clue if Earthly worlds could form in such systems. Given that at least half of all stars are binaries, the finding greatly expands the odds for life in the universe.



GU Psc b

Most hipster

Talk about outside the mainstream. GU Psc b set the record this year for the greatest distance from its star. This rebel planet hangs out in an orbit about 200 billion miles from its host star — about 2,000 times the average Earth-sun distance. As big as about a dozen Jupiters, GU Psc b's outsider status challenges leading planet formation theories.



Kepler-10c

Biggest beefcake

This burly world is the first-ever "mega-Earth." Scientists knew that Kepler-10c was a "super-Earth" — a planet a few times Earth's size — since discovering it in 2011. But these planets could range from gaseous mini-Neptunes to rocky Earth-like worlds. A new measurement of Kepler-10c's mass, however, confirmed the world is solid, having 17 times Earth's mass. It's the "Godzilla of Earths," one researcher quipped.



Kepler-186f

Most likely to succeed

Hopes that alien life might exist got a huge boost in 2014 with the discovery of Kepler-186f. It's the first Earth-size planet discovered in another star's not-too-hot, not-too-cold "Goldilocks" zone, where liquid water can persist on a planetary surface. Potentially the friendliest-to-life exoplanet yet found, Kepler-186f will be studied for years to come.

CLOCKWISE FROM TOP LEFT: ESO/L. CALÇADA; LUCAS GRANITO/OMM; NASA AMES/SETI INSTITUTE/JPL-CALTECH; DAVID A. AGUILAR (CFA)

EXOPLANET HIGH CLASS OF 2014



Kepler-413b
Biggest drama queen

There's always a moody one. Kepler-413b has a very wobbly orbit, research this year showed. As it orbits a pair of stars, the exoplanet dips above and below the plane of the stars' orbit in an 11-year cycle. Earth takes 112,000 years to complete such a wobble cycle. Unlike most "transiting" exoplanets — which, from our perspective, cross the faces of their stars like clockwork — Kepler-413b goes long periods without a transit because of its wild orbital swings. It won't transit again until 2020.



Kapteyn b
Most dependable

A loyal buddy, that Kapteyn b. This newfound exoplanet is 11.5 billion years old, more than twice our planet's age. But here's the kicker: Kapteyn b might well have been — or even may still be — habitable, as it, too, has an orbit that could allow liquid water. Life would have had many extra billions of years to develop here under the stalwart planet's dim, red sun.



Gliese 581 d and Gliese 581 g
The dropouts

Exoplanet High had a few big dropouts this year. Gliese 581 d and Gliese 581 g, touted as the first potentially habitable exoplanet back in 2010, both failed to make the grade. Closer scrutiny of the Gliese 581 system reveals that the dips in starlight thought to arise from these planets crossing in front are more likely just due to sunspots.

CLOCKWISE FROM TOP LEFT: NASA/JPL-CALTECH/T. PYLE; PHL/UPR ARECIBO/ALADIN SKY ATLAS; LYNETTE COOK/NASA; BACKGROUND: MEHMET CAY/THINKSTOCK

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(1) Mailed Outside-County Paid Subscriptions Stated on PS Form 3541	477,591	482,504
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e. Total Free or Nominal Rate Distribution (Sum of 15d (1), (2), (3), and (4))	250	250
f. Total Distribution (Sum of 15c and 15e)	525,841	514,254
g. Copies Not Distributed	195,509	169,546
h. Total (Sum of 15f and g)	721,350	683,800
i. Percent Paid (15c divided by 15f times 100)	99.95	99.95

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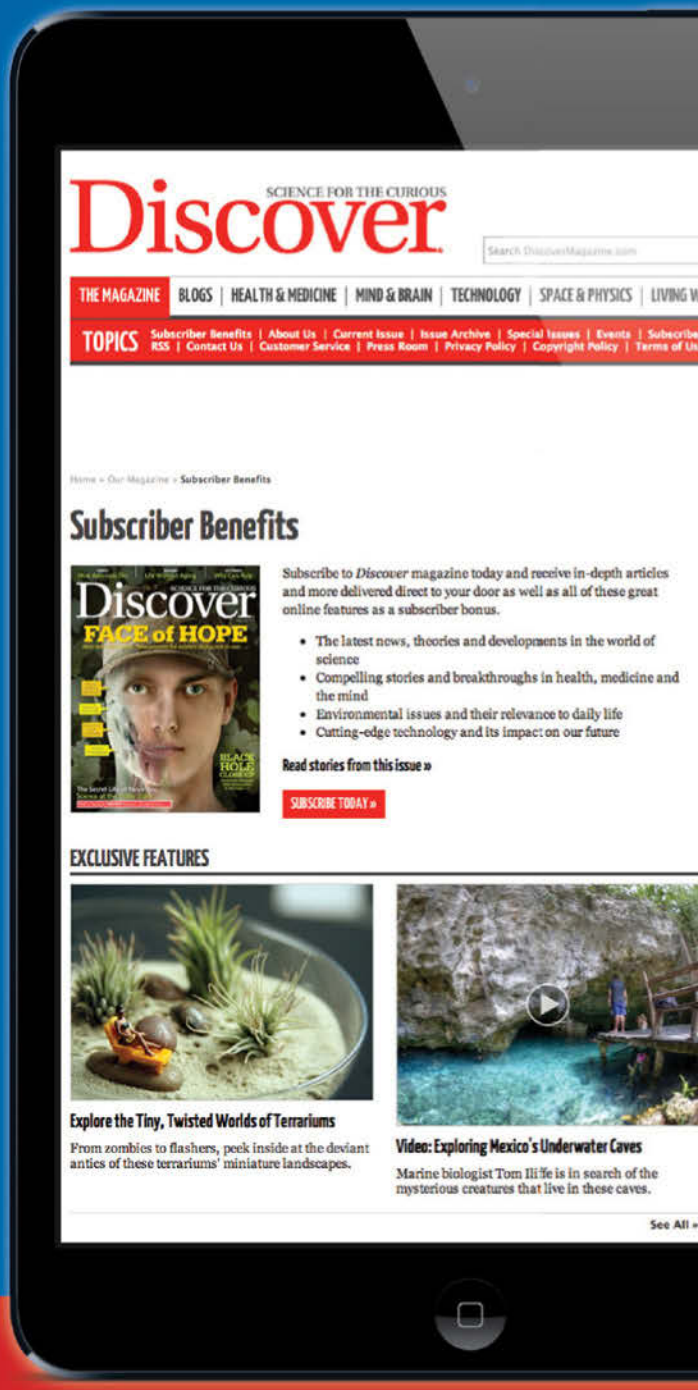
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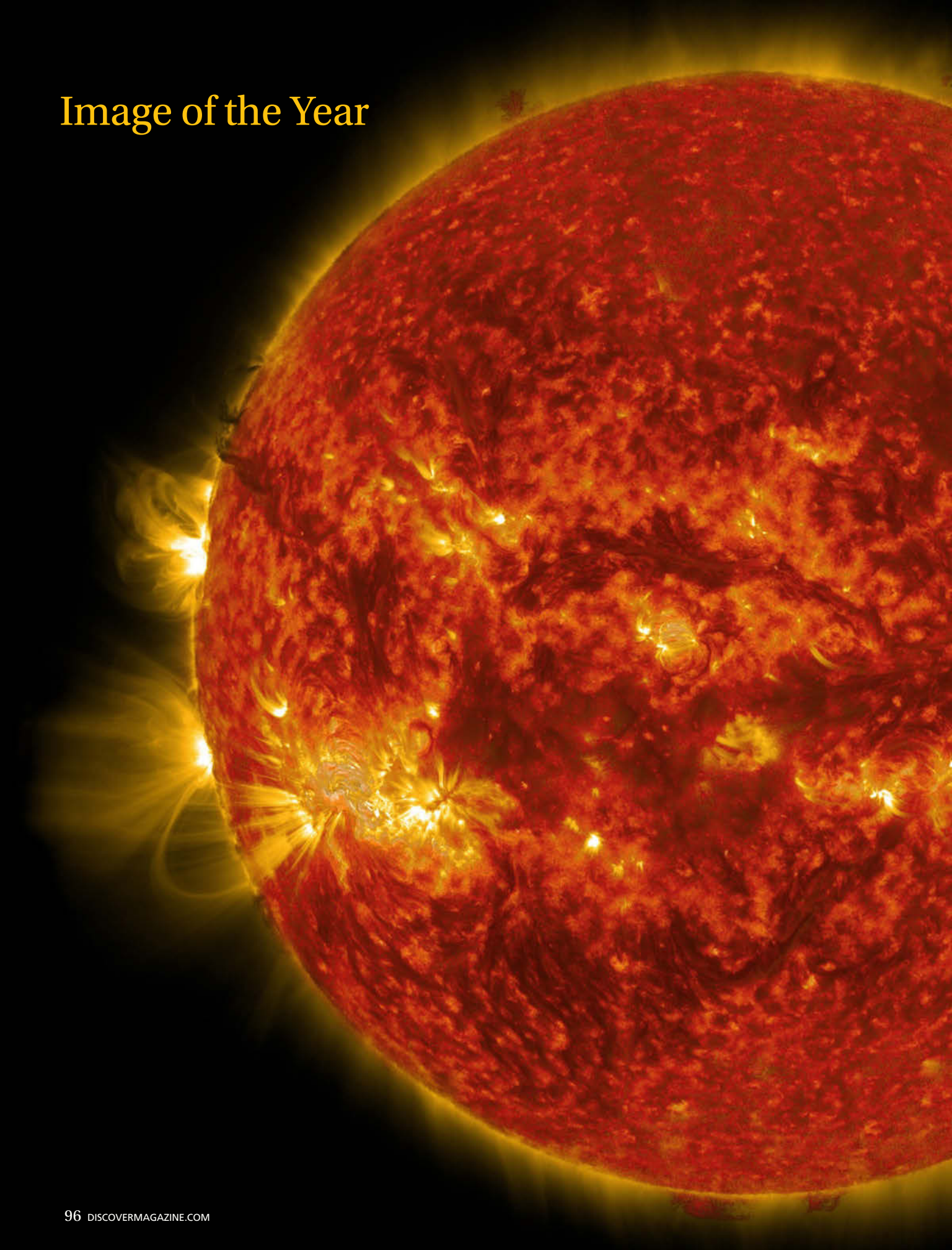
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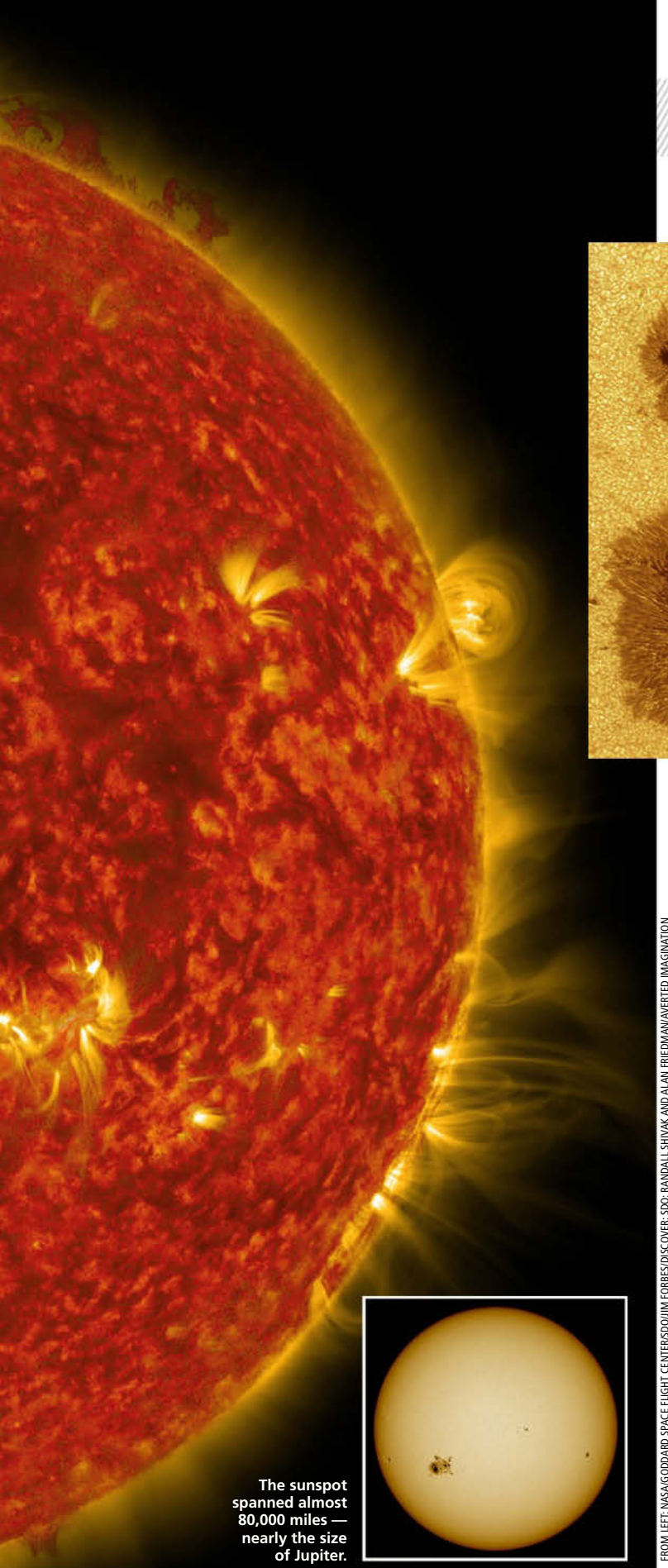
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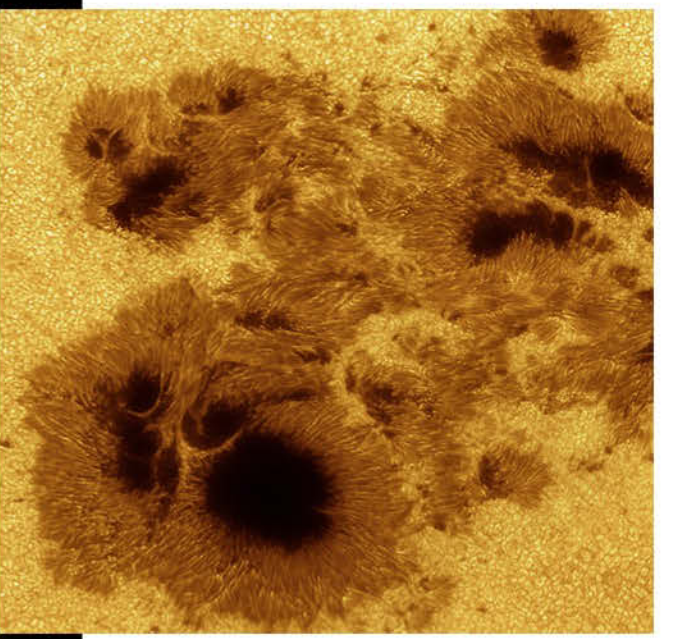
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Image of the Year





The sunspot spanned almost 80,000 miles — nearly the size of Jupiter.



This telescopic view reveals the sunspot group to be much darker in visible wavelengths. It could even be observed at sunset with the naked eye.

FROM LEFT: NASA/GODDARD SPACE FLIGHT CENTER/SDO/JIM FORBES/DISCOVER; SDO; RANDALL SHIVAK AND ALAN FRIEDMAN/AVERTED IMAGINATION

Our Sun Lets Out a Roar

Although the sun's current 11-year cycle of activity is one of the quietest ever recorded, this Oct. 20 image (left) is anything but calm. The composite combines different views of extreme ultraviolet light captured by NASA's space-based Solar Dynamics Observatory. The coronal loops — massive magnetic arches of hot gas — sizzle at 1.8 million degrees Fahrenheit (yellow), while plumes of plasma (red) simmer at a relatively cool 90,000 F.

In October, the area known as active region 12192 (the bright patch on the left side of the main image) spawned the largest sunspot group in 24 years. According to NASA solar scientist C. Alex Young, the region is unusual because it produced fairly large solar flares but not the huge coronal mass ejections that typically occur at the same time, sometimes damaging satellites. — ERNIE MASTROIANNI

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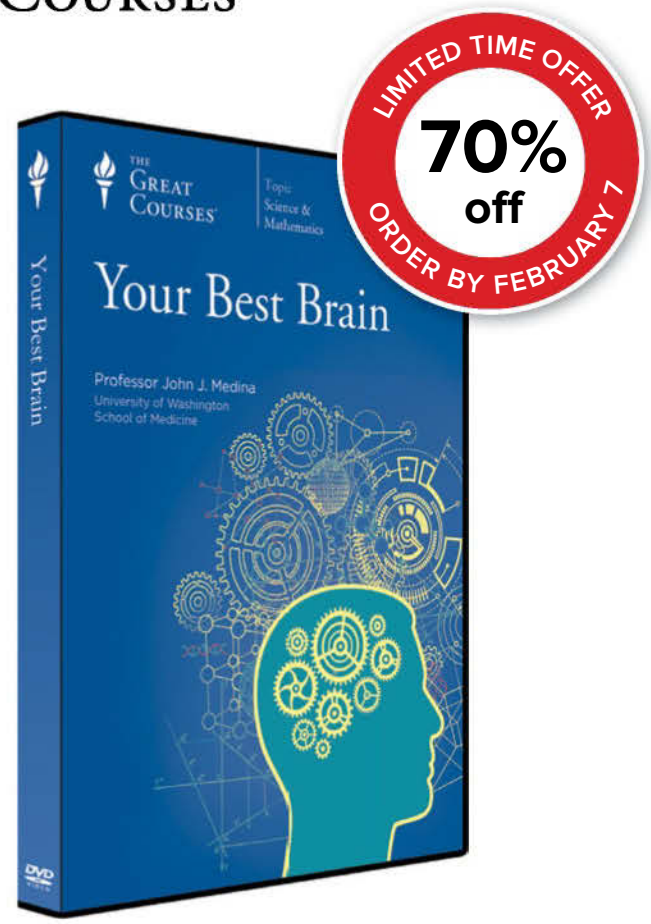
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